EVALUATION OF NECK SHAFT ANGLE AND ANTE VERSION IN DRY FEMORAE OF ADULT INDIAN POPULATION

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CERTIFICATE

This is to certify that this dissertation titled **"EVALUATION OF NECK SHAFT ANGLE AND ANTE VERSION IN DRY FEMORAE OF ADULT INDIAN POPULATION."** is a bonafide record of work done by **DR.T.MANIKANDAN,** during the period of his postgraduate study from July 2012 to September 2014 under guidance and supervision in the INSTITUTE OF ORTHOPAEDICS AND TRAUMATOLOGY, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai-600003, in partial fulfillment of the requirement for **M.S.ORTHOPAEDIC SURGERY** degree Examination of The Tamilnadu Dr. M.G.R. Medical University to be held in April 2015.

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DECLARATION

I declare that the dissertation entitled **"EVALUATION OF NECK SHAFT ANGLE AND ANTE VERSION IN DRY FEMORAE OF ADULT INDIAN POPULATION."** *submitted by me for the degree of M.S is the record work carried out by me during the period of* ***July 2012 to September 2014*** *under the guidance of* ***PROF.N.DEEN MUHAMMAD ISMAIL,*** **M.S.ORTHO., D.Ortho.,** *Professor of Orthopaedics, Institute of Orthopaedics and Traumatology, Madras Medical College, Chennai. This dissertation is submitted to the Tamilnadu Dr.M.G.R. Medical University, Chennai, in partial fulfilment of the University regulations for the award of degree of M.S.ORTHOPAEDICS (BRANCH-II) examination to be held in April 2015.*

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LIST OF ABBREVATIONS USED

AV	**anteversion**
FNA	**Femoral Neck Anteversion**
NSA	**Neck Shaft Angle**
LGP	**Longitutdinal Growth Plate**
TGP	**Trochanteric Growth Plate**
FNI	**Femoral Neck Isthumus**
NH	**Neck Horizontal angle**
CH	**Condyle –Horizontal Angle**
NPAR	**Non parametric test**
SE	**Standard Error**
SD	**Standard Deviation**
AP	**Antero Posterior**
R	**Right**
L	**Left**
MoM-HRA	**Metal on Metal-Hip Resurfacing Arthroplasty**
D	**Direct**
DHS	**Dynamic Hip Screw**
PFN	**Proximal Femoral Nail**
THA	**Total Hip Arthroplasty**
MRI	**Magnetic Resonance Imaging**
CT	**Computed Tomography**
SCFE	**Slipped Capital Femoral Epiphysis**
DDH	**Developmental Dysplasia of Hip**

EVALUATION OF NECK SHAFT ANGLE AND ANTEVERSION IN DRY FEMORAE OF ADULT INDIAN POPULATION.

Abstract:

<u>Introduction</u> -

The proximal end of the femur has been the object of much attention. Knowledge of its anatomy is a prerequisite for a complete understanding of the mechanics of the hip joint and serves as a basis for the treatment of pathological conditions of the hip and femur. Extensive studies of normal neck angles have been carried out. The values differ considerably in the reports available. Differences in methods used, differing anatomical definitions and variations between populations may account for this.

Aim : To evaluate the possible variation in the measurements of neck shaft angle and ante version by Direct ,X-ray and CT –guided values in dry femorae of adult Indian population. This correlation of measurements will help us to identify a simple, reliable radiological method to evaluate the proximal femoral angles and the data obtained in this study will help us to improve the implant and prosthesis design for Indian population and enhance the functional outcome of the patient.

Study type: analytical observational study – cross sectional type.

Materials and methods: 50 unpaired adult dry femorae of undetermined age and sex without gross pathology and abnormality from anatomy department ,MMC will be used as the study material. Immature bones, bones with abnormal pathology were excluded from the study.

ANTEVERSION:

Direct measurements by Kingsley Olmsted method

X-ray measurements were taken in dry femur by the method described by KOSUKE OGATA et al- Biplanar radiography method-from AP view and Lateral view of dry femur.

CT –measurements of anteversion were taken by measuring the angle between neck horizontal axis and condylar horizontal axis in dry femur scannogram.

NECK –SHAFT ANGLE: The collo diaphyseal angle between the head neck axis and the femoral shaft axis measured by direct, X-rays and CT methods.

RESULTS: The mean anteversion angle by Direct, X-ray and CT measurements was found to be 10.3°, 10.4°, 9.9° respectively. Among the three methods the CT-guided method seems to be more accurate to measure the ante version angle by Friedman test result. There was no significant difference in which side (right/left) the sample bone belongs to. The mean neck shaft angle by Direct, X-ray and CT measurements was found to be 131.9± 5.3, 130.3±4, 133.9±5 respectively. Among the three methods the X-ray method seems to be more accurate to measure the neck shaft angle by Friedman test result. There was no significant difference between right and left side bones.

CONCLUSION:

1. The simple biplanar radiography can be substituted as an alternative for CT measurements to determine the NSA and AV preoperatively,though CT –measurements give more accurate values.

2. The data obtained forms a strong base for future research in proximal femoral angles in adult Indian population.

3.The proximal femur angles varies for each person even in Indian population and the implants designed are mainly based on the data obtained from western population.These radiological methods helps us to obtain pre operative proximal femur angles to design specific implants to improve the efficiency of fracture fixation and functional outcome.

CONTENTS

INTRODUCTION

From the middle of 19th century proximal femur angles has been the object of much attention and debate in the orthopaedic literature .For the complete understanding of biomechanics of hip joint, knowledge of proximal femur anatomy is essential.[1] It also forms the basis for the management of various femur and hip joint pathologies. A vast collection of cultural , genetic and morphological characteristics exists in our Indian sub – continent [2]. In historical times, through large scale immigration into India, a considerable fraction of these characteristics has been introduced.[2]

Ante version is an important parameter for normal walking and for stability of the hip joint . Any decrease or increase in femoral ante version becomes the cause for various clinical scenarios. For corrective osteotomy, arthroplasty and for the manufacturing of modular as well as normal hip prosthesis a sound knowledge of normal ante version is essential.

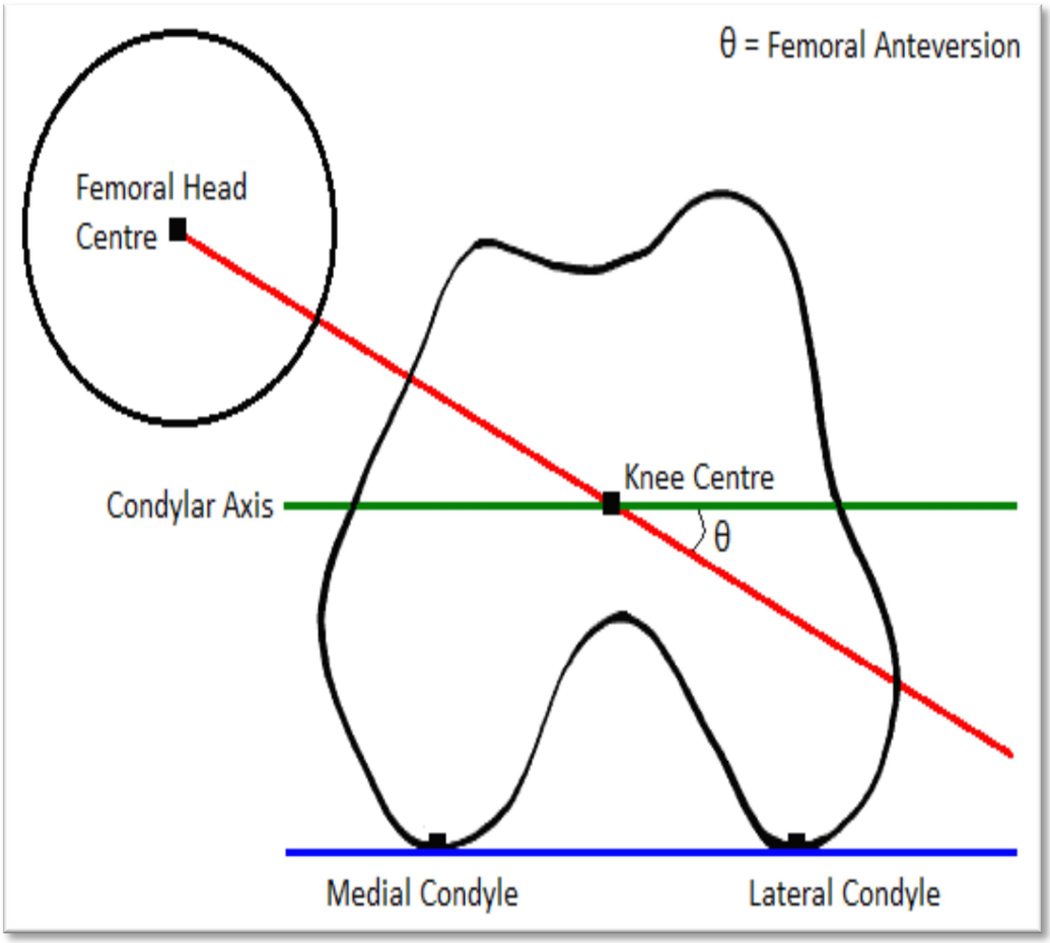
The femoral ante version angle (FNA) is defined as the angle formed by the projection of the femoral neck axis and the retro condylar axis.

The average adult femoral ante version has been documented to range between 7°-16° in multiple skeletal surveys, whereas Le Damany (1903)[9]quoted it to range from –25 to +37 degrees. It is influenced by the result of evolution, heredity, intrauterine position, and mechanical forces.

Abnormal FNA sometimes can be associated with many clinical problems ranging from harmless in toeing gait in the early childhood, which could be a reason for parents concern for children future, to disabling osteoarthritis of the hip and the knee in the adults. A increase in femoral ante version angle is associated with slipped capital femoral epiphysis, cerebral palsy, medial femoral torsion, apparent genu valgum, external tibial torsion, perthes disease and with failure of treatment in congenital dislocation oh hip joint. At the same time , a decrease in femoral ante version is associated with rickets, out toeing gait, chondro dystrophy and torn acetabular labrum of hip .

Measurement of femoral orientation _ Femoral anteversion (Murphy et al., 1987)[8]. Femoral version, in a joint coordinate frame is regarded to be the angle between the femoral neck axis and the coronal plane (Ko and Yoon, 2008; Seki et al., 1998; Yoshimine, 2006). It has been defined clinically by Murphy et al. (1987)[8] as the angle between the femoral neck axis and an axis parallel to the posterior aspect of the femoral condyles, measured in the transverse plane. This axis is known as the condylar axis and is shown in Figure 1.a. The condylar axis is used to define the neutral rotation of the femur. Therefore, it is coincident with the coronal plane of the hip joint(Maruyama et al., 2001).[9]

Fig 1.a : Condylar axis defining the neutral rotation of femur



The neck-shaft angle (NSA) is the angle formed by the head neck axis and the long axis of the femur. The femoral neck connects the head to the shaft at an angle of about 125 degrees which facilitates movement at the hip joint, enabling the the hip to maintain its normal biomechanics. This angle varies with age, stature, & width of pelvis, being less in adult, in persons with short limbs, and in women (Romanes, 1981).[3]

The degree of the diaphysio-femoral neck angle according to Wagner and colleagues varies from 125°3' to 132°3'. On the other hand, it was reported that the value may fluctuate from 109° to 153°, with no gender or racial predilection (Samaha, 2008).[4] At the same time, several studies have shown that the neck shaft angle is very stable from mid adolescence through most of adulthood (Humphrey, 1889; Trinkaus, 1993)[5,6]. Femoral neck-shaft angles show considerable variation within the human population. Mean values range from 122°±136°, and in normal individuals are found from around 110° to almost 150°[5,6]. Geography, climate and race appear to have little effect on patterning in femoral neck-shaft angles and ante version (Anderson, 1998)[7] .

In our country , floor level activities like squatting, personel hygiene require an extreme range of movements in hip joint . Evolutionally and morphologically this makes the Indian hips to differ from the western population.

The neck shaft angle guides the clinician to detect and diagnose a femoral neck fracture. At present in developing countries like our India, mostly the standard size implants are in clinical practice. But measurement of parameters show variation from individual to individual.Over hanging / undersized femoral implant can result in complications like altered patella femoral stresses and altered soft tissue tensioning . Defeciency or the unavailability of the accurate size femur implants can trouble the patient in long run.

Accurate measurements of neck shaft angle and ante version is of prime importance in pre operative planning of dynamic hip screw fixation, proximal femoral nailing, de rotation osteotomy, total hip replacement and other commonly performed orthopaedic surgeries to maintain normal hip dynamics. Many number of methods have been applied to measure the proximal femoral angles with their own advantages and disadvantages .

Direct measurements, image assisted techniques like USG, mono planar and bi planar axial Roentgenography, axial computed tomography, 3D-reconstruction studies, MRI have been used to measure the ante version and neck shaft angle of femur. The values differ considerably because of different methods used and inter population variation(ethical). Due to various confounding factors, to get the expected results in clinical practice is not always possible. Hence in clinical practice every ideal method designed to deliver an accurate value has failed.

We have a very scarce data regarding the neck shaft angle and ante version of femur in Indian population. The standard implants we use in our patients are designed on the data obtained from the western population, which may not be applicable to them.

With these concepts in mind , Our study wish to evaluate the neck shaft angle and ante version in dry femorae of adult Indian population by direct measurements , bi planar radiography , axial computerised tomography to analyse and interpret the values obtained

Measurement of Femoral orientation-Femoral neck-shaft angle (λ) (Maruyama et al. , 2001)[9]

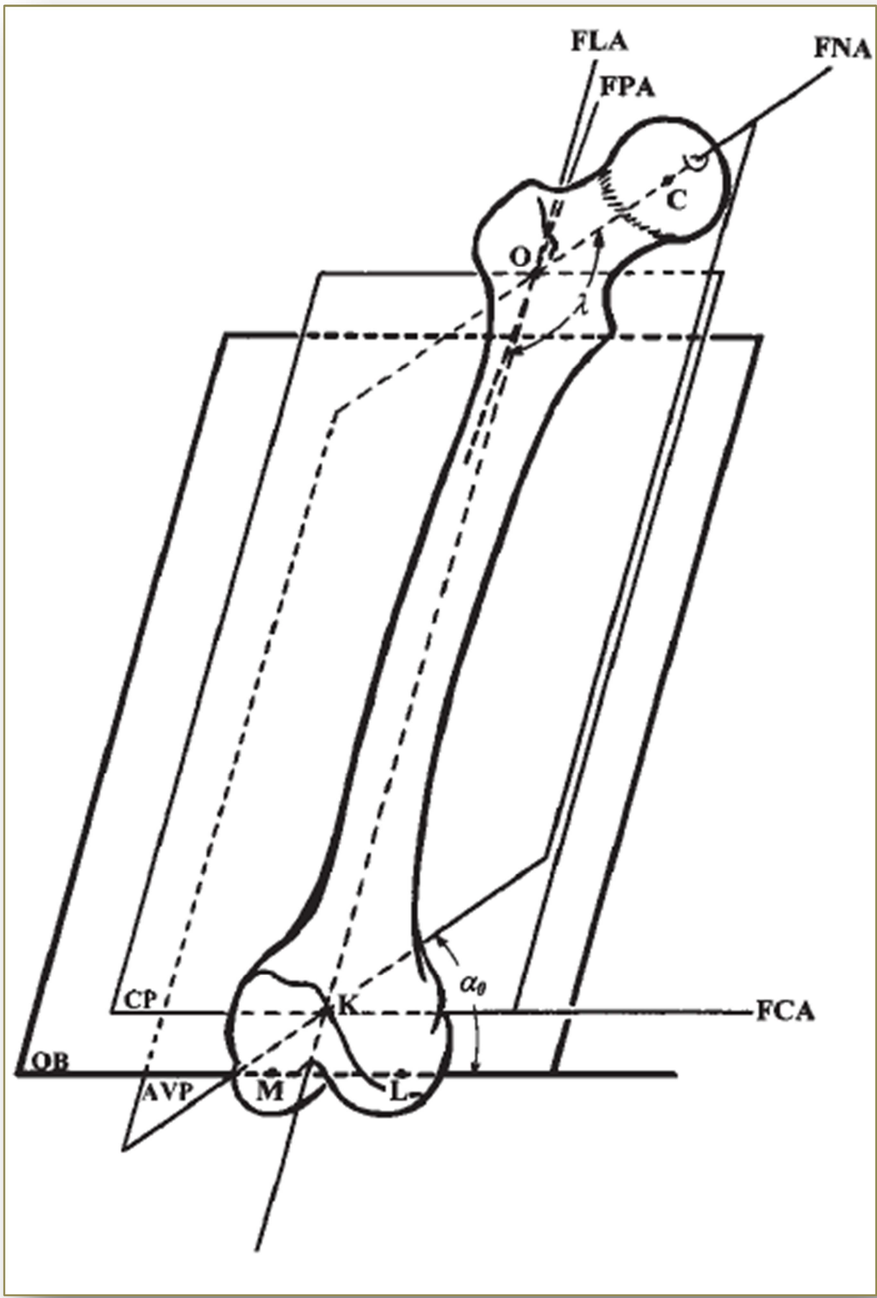


Fig 1.b :Femoral orientation –femoral neck shaft angle.

FLA - LONGITUDINAL AXIS OF FEMUR

FNA - FEMORAL NECK ANTE VERSION

FCA - CONDYLAR AXIS OF FEMUR

λ - FEMORAL NECK SHAFT ANGLE.

K - CENTRE OF KNEE

O - BASE OF FEMORAL NECK

AP - PLANE OF ANTE VERSION

CP - CONDYLAR PLANE

Θ - ANTE VERSION ANGLE.

The femoral neck-shaft angle is defined as the angle between the femoral neck axis and the longitudinal axis of the femur, shown as symbol λ in Fig 1.b (Maruyama et al., 2001).[9]

AIM OF THE STUDY

1) To evaluate and analyse the neck shaft angle and anteversion in dry femorae of adult Indian population by

   a. Direct measurement

   b. image assisted methods (X-ray and CT)

2) To analyse and statistically correlate the results obtained from the above methods to :

   a. identify any variation in measurements by three different methods.

   b. to propose a simple , reliable method to measure neck shaft angle and ante version for clinical application.

REVIEW OF LITERATURE

In orthopaedic literature ,the relation between head, neck and the proximal shaft is of much interest and debate way back from the middle of 19th century. A huge number of research work targeting the measurement of proximal femur angle and defining the parameters has been developed ,since the proximal femur is an area susceptible to various adult and paediatric disorders in orthopaedics.

The earliest efforts to quantify the proximal femur dimensions began with examining the relationship between the femoral shaft and neck. Two well known parameters NSA and FNA have long defined this relationship. Although the former of these two measurements has a widely accepted theoretical definition and standard radiographic method of determination, the latter has produced more than a century’s worth of investigation regarding its true definition, normal values and preferred method of measurement. Although the relationship between the shaft and neck of the femur has been quantitatively scrutinized by numerous authors for more than a century, critical evaluation of the head-neck relationship is still in relative infancy.

The first radiological measurement of neck shaft angle and ante version should probably have done sometime after the accidental discovery of X-rays by Sir Wilhelm Roentgen. But in 1903 Soutter and Bradford first published a report in measuring femoral ante version. According to him , it was necessary to get a x-ray done with the foot in such a position, so that it points forward and from the centre of the head to assess the degree of ante version. In 1909 , in cases of developmental dysplasia of hip, Turner measured the femoral ante version by the method described by Soutter and Bradford.[10]

Farell ,Von Lackum and Smith in 1926 estimated the femoral ante version by getting two X-rays done with limb in two different positions. One X-ray was taken with leg and knee facing upward and the other X-ray with maximum medial rotation. In 1924 Parson.[11] took a sample of 134 dry femorae from the British population and estimated the neck shaft angle mechanically. Parson estimated the neck shaft angle to be $126.3\pm5.6^{\circ}$ in the given population[11]. Krida, Carr and Colona published the measurement of ante version by clinical and radiographic method in 1926. Karshner R G and Stewart S F demonstrated a fluoroscopic method in the same year. Again in 1928 , Krida took two X-rays one with knee directed sagitally and second one with inward rotation of leg. Twenty six museum specimens with Developmental dysplasia of Hip were studied by Fair Bank in 1930 and found the femoral ante version ranging 0° to 75° with an average of 30.6°.

A fluoroscopic method was introduced by Rogers et al in 1935.In this method the patient was made to lie in prone position with knee flexed to 90° until the neck and head of femur got super imposed .The degree of rotation required for super imposition was taken as the femoral ante version.[12]

Kingsley – Olmsted proposed a method to measure directly the femoral ante version in dry femur and provided a valuable data record on the normal ante version angle and mean values in 1948[13].This method is still considered as an ideal method for the direct method to measure the ante version in dry femur.

Dunn et al [14] in 1952 first used bi planar radiography for measuring femoral ante version. With knee and hip flexed to 90°, patient was made to lie supine and axial X-ray was taken. Difficulty in determining the axis of the neck and a very high penetration dose of radiation in heavily built individuals was the disadvantage in his method.

Dunn lap et al[15] demonstrated a similar radiographic method to measure the femoral ante version with thighs abducted, in 1953.In the same year ,to measure ante version axial radiographs with 30° abducted thighs were taken by C.T. Ryder and Lawrence .They required a special apparatus to position the patient.

To measure femoral ante version horizontal lateral roentgenography was taken by D.J. Maggilligan in 1957.[16]

A simple bi planar method was proposed by Kosuke Ogata et al[17] in 1972 to evaluate the neck shaft angle and ante version . He took AP view and trans lateral view of the femur . Without any complicated procedures he marked the head neck axis and femoral shaft axis simply by eye in the obtained X rays. Trignometric functions and graphs were used to measure the proximal femur angles. The data provided by this method was accurate enough to apply the measurements for clinical use. It is still considered as one of the simple and reliable method to measure the proximal femur angles.

In 1980 D S Weiner [18]studied the – practical considerations in the use of computed tomography in the measurements of femoral neck ante version. In addition to being accurate, the procedure requires no complicated positioning framework and can be done in a brief span of time.

A method using computed tomography was applied by Murphy et al in 1987.[8] 5mm axial cuts of the proximal femur were made and super imposed to obtain the true neck axis and ante version was measured.

Using the tilted transducer technique , Anda S measured the femoral ante version by ultra songraphy in 1988.

A clinical method was described by Patrick A Ruwe et al[15] in 1992.He made the patient to lie in prone position with knees flexed to 90^{o} and rotated the leg till the maximum prominence of the greater trochanter was reached. From the degree of rotation of leg , he calculated the ante version angle.

A comparision of CT and MRI measurements of the proximal femur angle was made by Tomczak et al in 1997[19]. He reported a good correlation between the two measurements. MRI is useful and safe in paediatric age group.

A comparision of ante version measurements in human cadaveric femur using axial CT cut and axial oblique reformations was made by Delma Y Jarrett et al in 2010.[20] Accuracy changes across the range of simulated femur positions was observed. This study revealed that axial oblique cuts were superior in accuracy than simple axial cuts.

Indian literature on femoral ante version

In 1963 Kate et al[21] Studied the ante version in dry 108 dry bones by direct measurement and found the ante version to be 8.8°.

In 2003 RC Siwach et al [22] measured the ante version in dry bones of Indian population in Rohtak region with a sample size of 150 by X-ray methods and found the mean ante version to be 13.7° with a standard deviation of 7.3°.

A comparative study for measuring femoral ante version by three methods- clinical, bi planar radiography and pre operative measurement were made by A V Maheswari, AK Jain et al,[23,24] in 2004.They reported the correlation between bi planar and pre operative methods was inferior to clinical and pre operative methods.

A V Maheswari , AK Jain et al,[23,24] in 2005, did a study of comparing Kingsley- Olmsted method and CT method with that of bi planar radiography and clinical method for measuring ante version of femur .In their study the clinical method and CT measurement correlated well, than the X-ray method.

K C Saikia et al,[2] in 2008 ,studied the hip joint anthropometry of Indian population in the north-eastern region by CT guided measurement. The mean ante version was found to be 20.4° which was considerably high than the ante version reported in western literature.

In 2010 A Zalawadia et al, [25] measured the ante version in dry bones directly in Gujarat population and reported it as 12.4°.

In 2012 T Shrimathi, Muthukumar et al, [26] measured the dry bones ante version with a sample size of 164 directly and reported as 9.8°.They described the measurement of ante version and its clinical application.

Indian literature on Neck shaft angle

B Issac et al[27] in 1997 , directly measured the neck shaft angle in 177 dry femorae belonging to Vellore population of Tamil nadu and found the mean neck shaft angle to be 126.7º

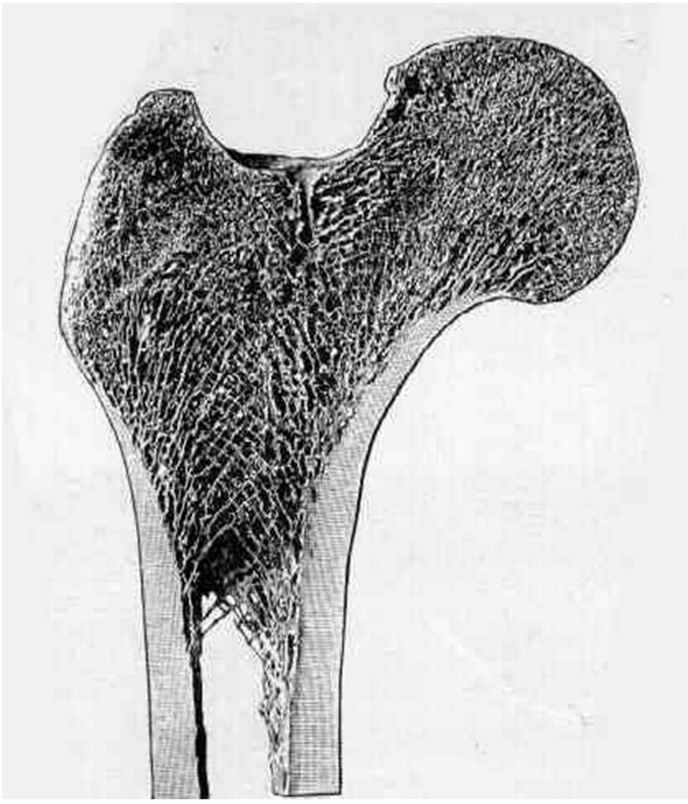
R C Siwach et al[22] in 2003, with a sample size of 150 measured the dry bone neck shaft angle by direct and CT methods. The sample was from the population of Rohtak (India). In this study the direct and CT measurement correlated well and the mean was 123° with a standard deviation of 4.3º

In 2008 KC Saikia et al,[2] measured the neck shaft angle in general population by CT methods from people belonging to Guwahati region. The mean neck shaft angle was 139.5° with a standard deviation of 7.5°.

In 2011 Ravichandran et al, [28]with a large sample size of 578 dry femur measured neck shaft angle directly and described the mean neck shaft angle as 126.5°. In his study the mean neck shaft angle was lesser in South Indian population ,than the western and north Indian population.

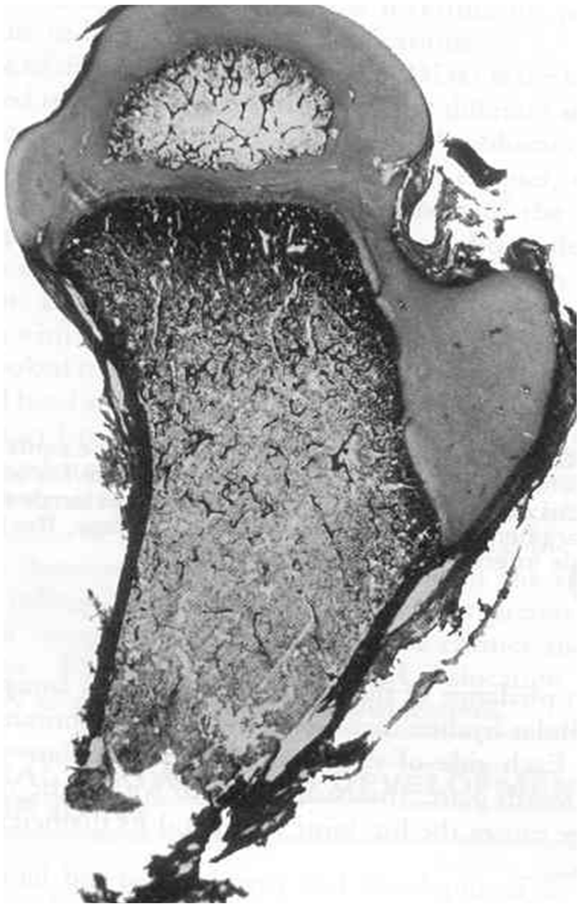
PROXIMAL FEMUR ANATOMY

EMBRYOLOGY:



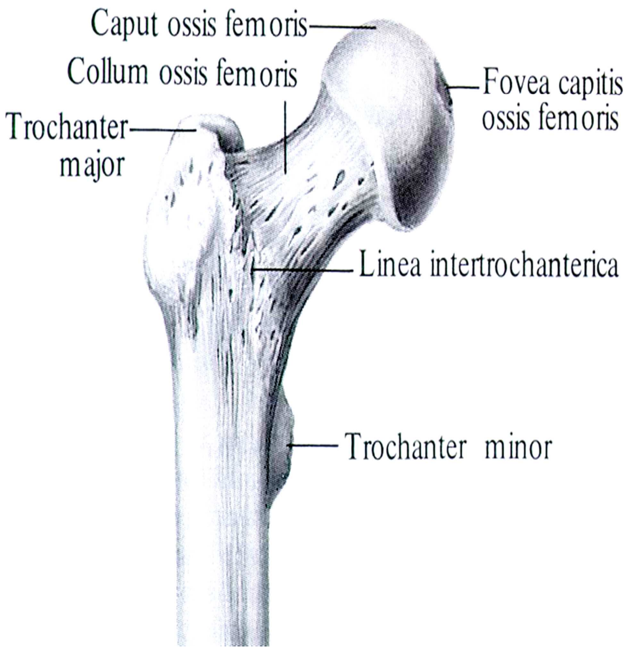
The proximal femur develops from four ossification centres. At birth, the ossified portion of the femur has progressed proximally to the level of the greater trochanter and the femoral neck.

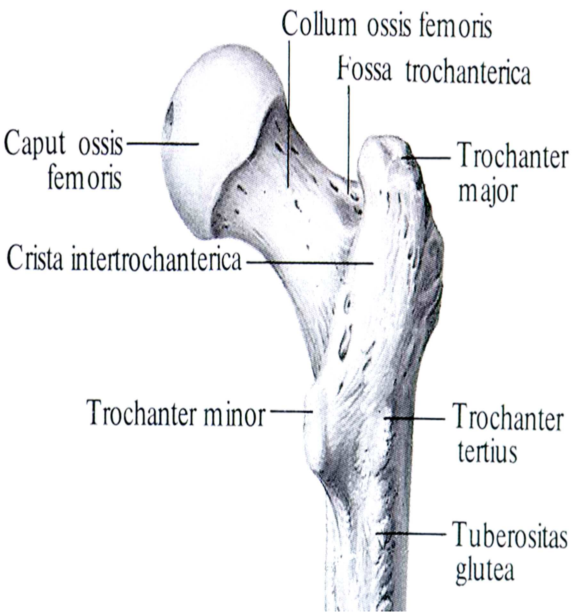
Three separate growth plates define the cartilaginous proximal femur: the longitudinal growth plate (LGP) of the femoral neck, the growth plate of the greater trochanter (TGP), and the connecting growth plate on the lateral neck called the Femoral neck isthumus(FNI) .

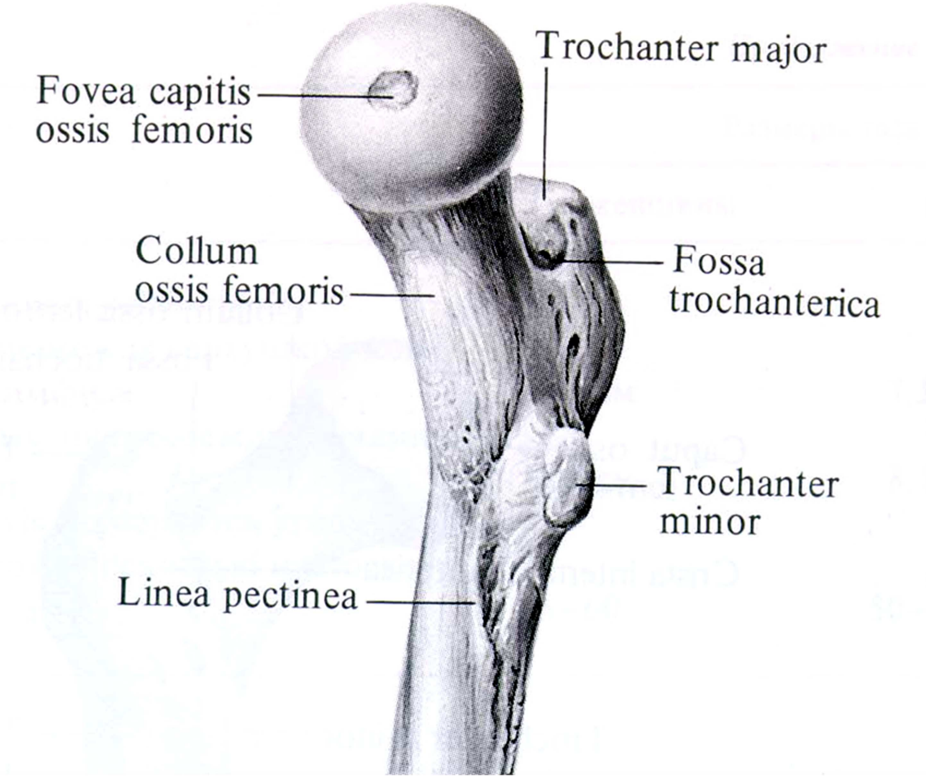


The LGP and the TGP have divergent growth vectors that additively create longitudinal growth of the proximal femur along the axis of the femoral shaft. Alterations in growth of either of these physes result in angular deformities of the mature hip. Additionally acting on the LGP is contact pressure from the acetabulum, which forces spherical appositional growth within the socket. The mature shape of the femoral head and that of the acetabulum are inter-related and rely heavily on the dynamic and continuous reciprocal relationship of the round head in the round socket.

Proximal femur







The proximal femur consists of:

1.Caput femoris (head).

2.Collum femoris(neck).

3.Greater trochanter.

4.Lesser trochanter.

Caput femoris

The femoral head faces antero supero medially to articulate with the acetabulum. The head, often described as rather more than half a ‘sphere', is not part of a true sphere but is spheroidal. Its smoothness is interrupted posteroinferior to its centre by a small, rough fovea. The head is intracapsular and is encircled, distal to its equator, by the acetabular labrum. Its articular margin is distinct, except anteriorly, where the articular surface extends on to the neck. The ligamentum teres is attached to the fovea.

Collum femoris

The femoral neck is approximately 5 cm long, narrowest in its mid part and widest laterally, and connects the head to the shaft at an average angle of 135° (angle of inclination; neck–shaft angle)[29]. This facilitates movement at the hip joint, enabling the limb to swing clear of the pelvis. The neck also provides a lever for the action of the muscles acting about the hip joint, which are attached to the proximal femur.

The neck–shaft angle is widest at birth and diminishes gradually until adolescence; it is smaller in females. The neck is laterally rotated with respect to the shaft (angle of anteversion) around 10–15°, although values of this angle vary between individuals and between populations (Eckhoff et al 1994).

The contours of the neck are rounded. The upper surface is almost horizontal and slightly concave, the lower is straighter but oblique, directed inferolaterally and backwards to the shaft near the lesser trochanter. On all aspects, the neck expands as it approaches the articular surface of the head. The anterior surface of the neck is flat and marked at the junction with the shaft by a rough intertrochanteric line. The posterior surface, facing posteriorly and superiorly, is transversely convex, and concave in its long axis; its junction with the shaft is marked by a rounded intertrochanteric crest.

Greater trochanter

The greater trochanter is large and quadrangular, projecting up from the junction of the neck and shaft. Its postero superior region projects supero medially to overhang the adjacent posterior surface of the neck and here its medial surface presents the rough trochanteric fossa.

The proximal border of the trochanter lies approximately a hand's breadth below the iliac tubercle, level with the centre of the femoral head. It has an anterior rough impression. Its lateral surface, continuous distally with the lateral surface of the femoral shaft, is crossed antero inferiorly by an oblique, flat strip, which is wider above.

Lesser trochanter

The lesser trochanter is a conical posteromedial projection of the shaft at the postero inferior aspect of its junction with the neck. Its summit and anterior surface are rough, but its posterior surface, at the distal end of the intertrochanteric crest, is smooth. It is not palpable.[29]

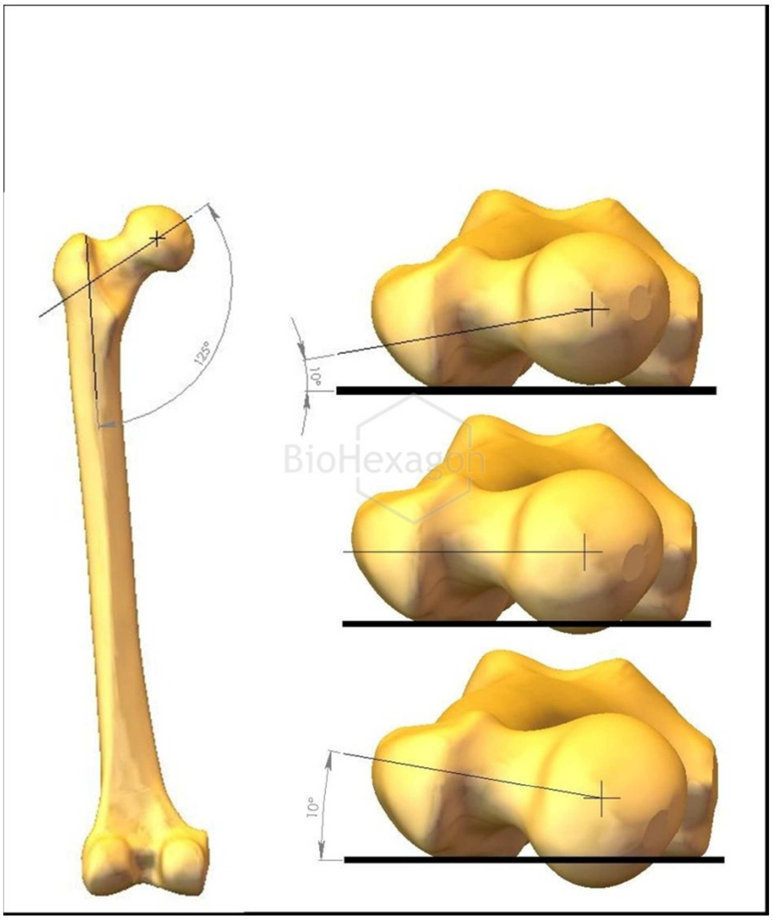
Factors influencing Neck shaft angle

The angle is widest in infancy, and becomes lessened during growth, so that at puberty it forms a gentle curve from the axis of the body of the bone. In the adult, the neck forms an angle of about 125° with the body, but this varies in inverse proportion to the development of the pelvis and the stature.

The angle decreases during the period of growth, but after full growth has been attained it does not usually undergo any change, even in old age; it varies considerably in different persons of the same age. In the female, in consequence of the increased width of the pelvis, the neck of the femur forms more nearly a right angle with the body than it does in the male. It is smaller in short than in long bones, and when the pelvis is wide.

Development of ante version

The femoral neck ante version (FNA) can be defined as the angle formed by the femoral condyles plane (bi condylar plane) and a plane passing through the centre of the neck and femoral head.[9] If the axis of the neck inclines forward to transcondylar plane the angle of torsion is called anteversion,if it points posterior to the trans condylar plane it is called retroversion and if the axis of neck is in the same line of transcondylar plane it is known as neutral version .



At 7 weeks of gestation femoral neck ante version is reported to be -10º.With gestational age, it gradually increases to 0º at three months,+12º at fifth month and at birth +24º.By detorsion it changes throughout the childhood and adolescence period until the average adult femoral anteversion angle of +12° is reached.[30,31,25.]The mechanism by which the femur undergoes torsion is unclear. The recent data is that ,the femur twists to the torsional forces. The torsional forces are perpendicular to the epiphyseal growth plate.(Cibulka)[32]

Based on Huenter –Volkmanns law of epiphyseal pressure,the pressure across the epiphysis is inversely proportional to the rate of growth. This law cannot be applied for adults since the epiphysis is closed. The change and remodelling in adult bone can be explained with Wolff's law. The Wolff's law states that , in accordance with mathematical laws, bones internal and external architecture changes with every change in form and function of the bone. [33]

The greatest stress to the bone i.e the torsional forces is contributed by the muscle either in its passive elastic connective tissue state or the contractile state. [32,33]

Materials and methods

This study was conducted in our Institute over 2 years period from 2012-14 with permission from ethical committee and with proper guidance from the Bernaud Institute of Radiology and Institute of Anatomy.

Inclusion criteria

50 dry femorae from the Institute of anatomy, Madras Medical College, were taken as the sample for the study .

Exclusion criteria

Immature bones, bones with abnormal pathology were excluded from the study.

The neck shaft angle and ante version angle from the dry femorae was measured by three methods:

1. **Direct measurement**: Kingsley Olmsted method used for measurement of anteversion.[13]

2. **Simple bi planar method-** Radiographic method by Kosuke Ogata et al.[17]

3. **Multi slice axial computed tomography-**Murphy et al.[8]

Direct measurements was used as reference value. The data obtained by other two methods were compared with the reference value.

Fig 2.a : Dry femur sample –left side

Fig 2.b : Dry femur –right side

DIRECT MEASUREMENT

Neck shaft angle

The angle formed between the femoral shaft axis and head neck axis is the neck shaft angle. The femoral shaft axis is identified by joining the line from the pyriform fossa(trochanteric fossa) to middle of femoral shaft measured , 2cm below the vastus ridge with the help of vernier calliper. The head neck axis is identified by the line joining the midpoint of femoral head in its centre and the midpoint of femoral neck at is base(midpoint identified using vernier calliper).The angle formed between these two axis was taken as the neck shaft angle .

Fig .2.c: Dry femur sample.

Fig .2.d Dry femur sample - demonstrating the head neck axis and femoral shaft axis.

Direct measurement of ante version

Ante version

Kingsley –Olmsted method was used to measure the ante version in dry femur in this study. The specimen was placed at the edge of the horizontal surface of table, so that the condyles of the inferior end rest on the surface. The horizontal limb of a gonio meter was fixed at the edge of the experimental table. The vertical limb was held parallel along the axis of the head and neck of the femur. The horizontal surface represents the retro condylar axis and the plane of reference against which the ante version is measured with the help of the axis of head and neck of the femur. The angle subtended was recorded.

Fig .2.e. : Vernier Caliper

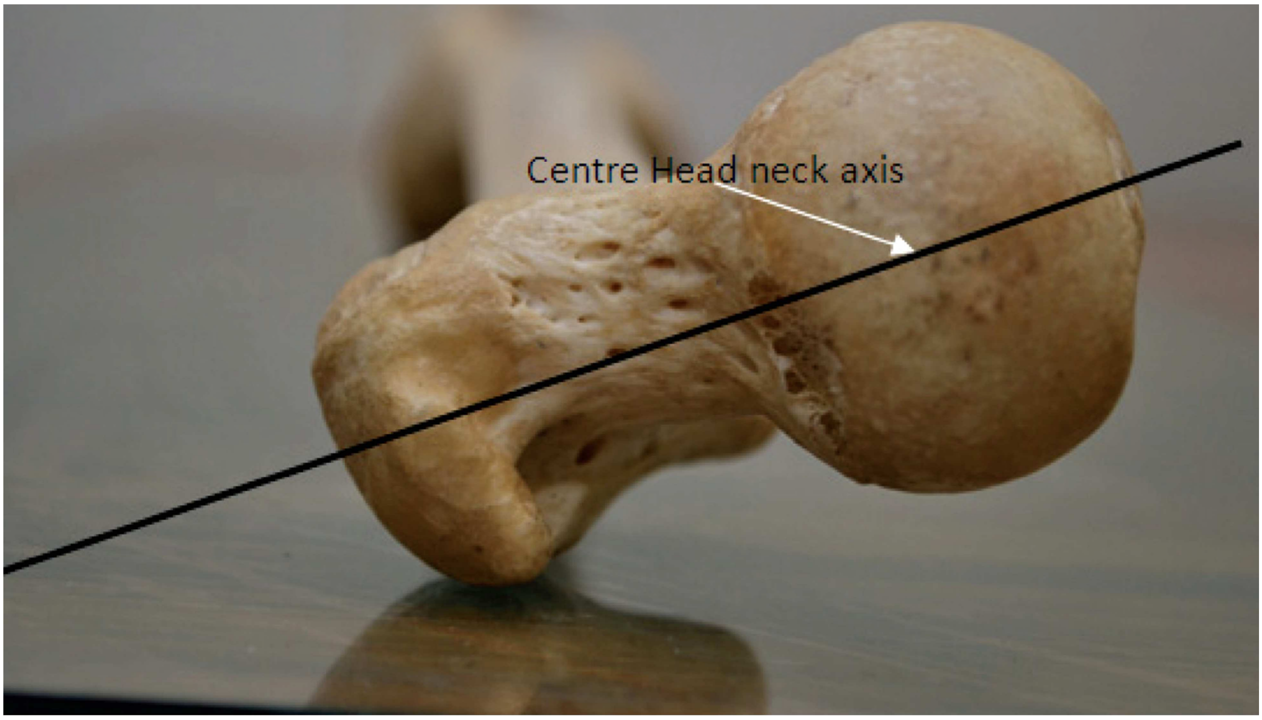


Fig 2.f : Demonstrating the head – neck axis.

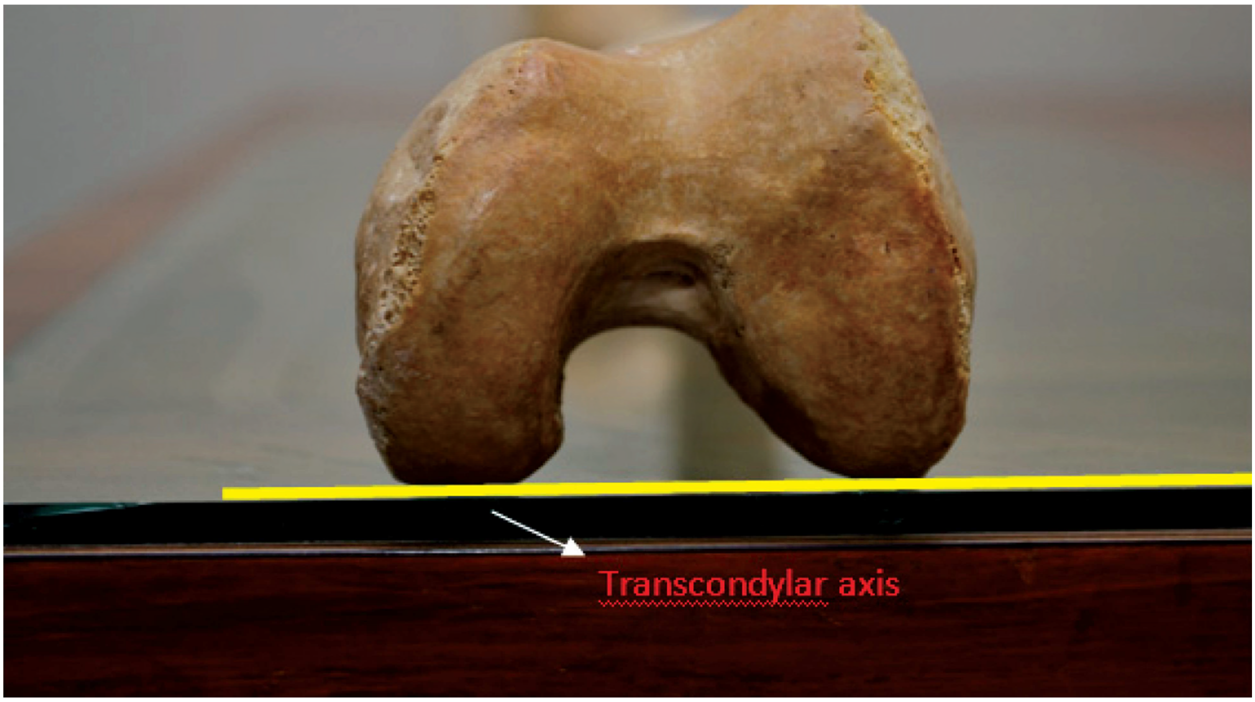


Fig 2.g : Demonstrating the trans condylar axis.

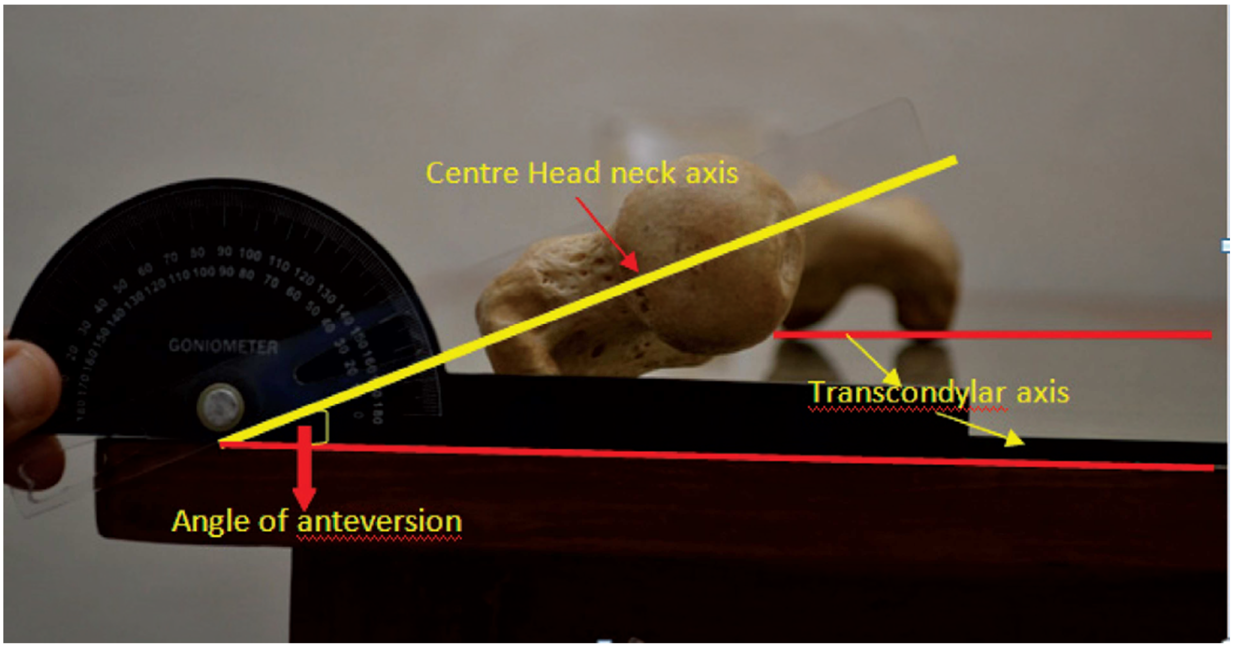


Fig 2.h : Demonstrating the measurement of ante version.

Fig 2.i : ante version of other samples.

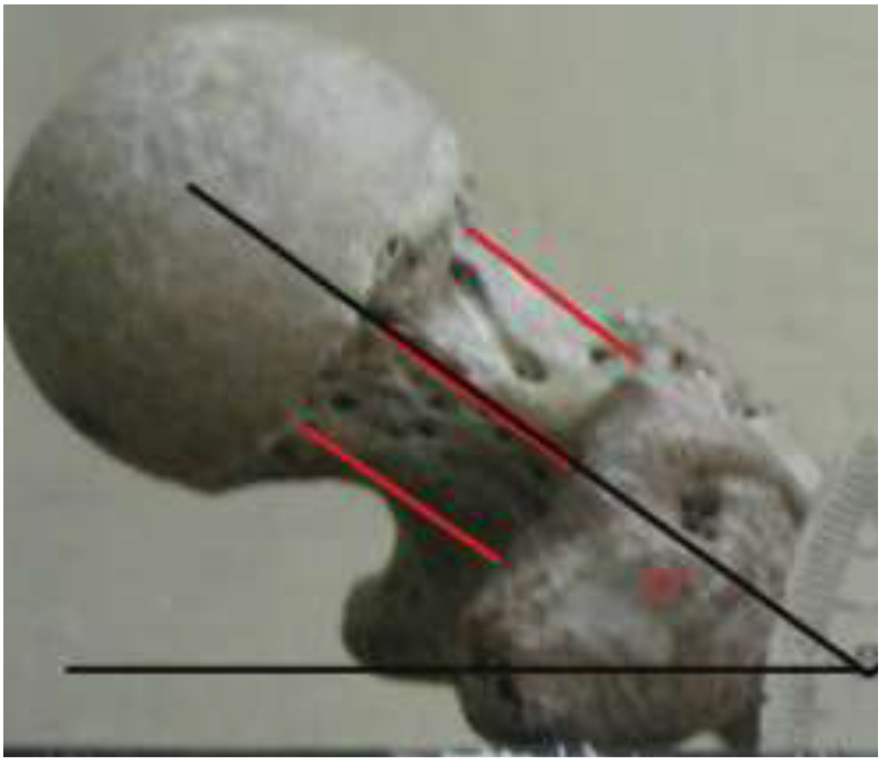


Fig 3.a : Demonstrating the centre of head ,centre of neck and the angle of ante version measurement.

Fig 3.b : Demonstrating the neutral version in observed samples.

Fig 3.c : Demonstrates the neutral , normal ante version and increased ante version in the sample observed .

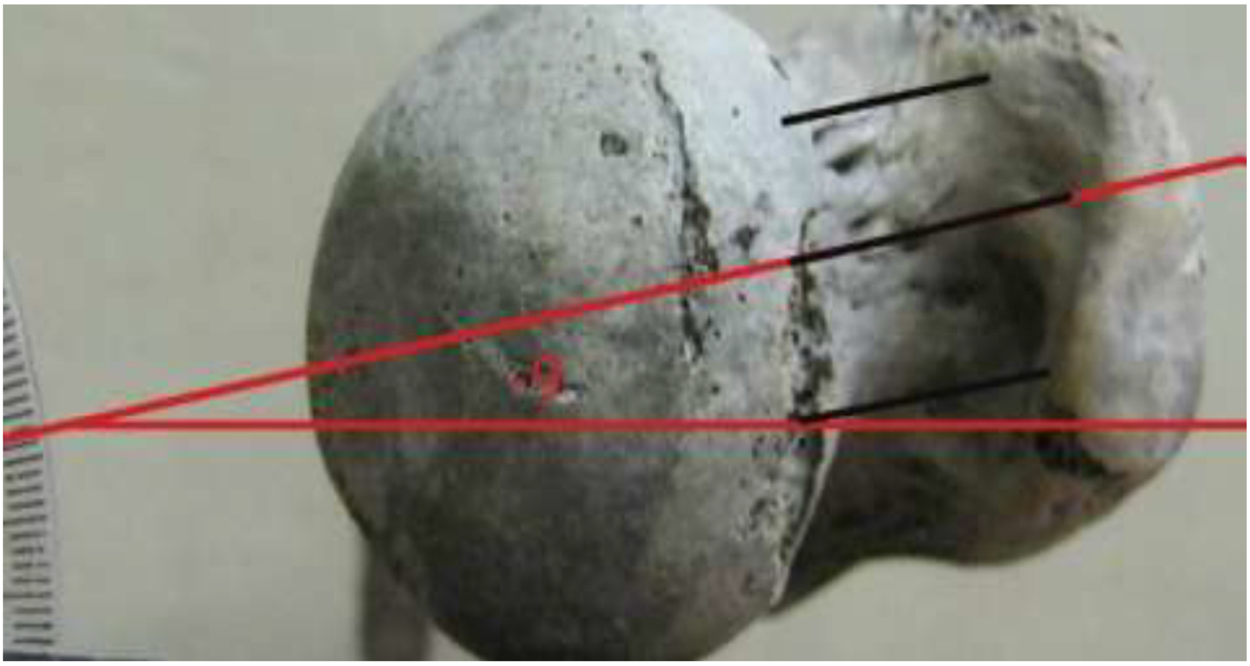


Fig 3.d: Demonstares the measurement of retro version.

Fig 3.e : Demonstrates the neutral version measurement.

BI PLANAR RADIOGRAPHY

The method of Kosuke Ogata et al was used[17]. The femur is kept in its anatomical position on the radiolucent x-ray table about 10 cms above the detector so as to simulate the natural position of femur while taking x-rays in a clinical setting. The source was then placed 125cms above the detector focusing over the lesser trochanter and the AP view is taken. The height of the source was set at maximum to minimize errors due to magnification.

A lateral view is taken by tilting the source and screen by 90º. The femur is left in the same position. The acute angles between the long axis of the shaft and the axis of the femoral neck are measured in the AP (α) and lateral views (β) . The cervico femoral projection angle and the angle of ante version were calculated.

Demonstration of antero posterior view

Fig 4.a

Fig 4.b

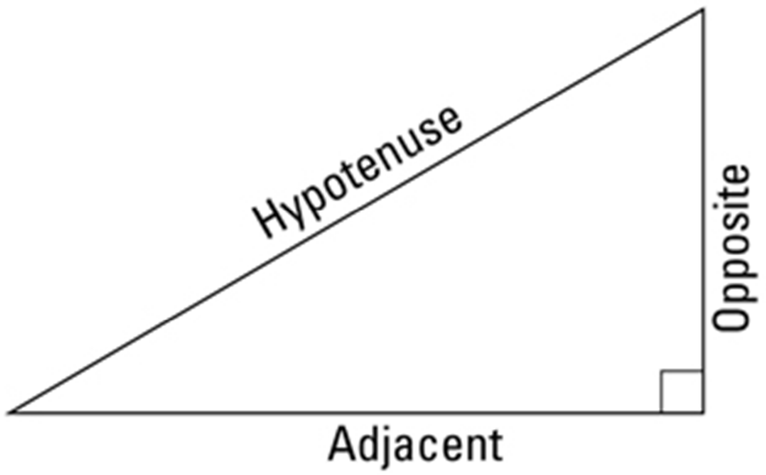
Demonstration of lateral view:

Fig 4.c

Fig 4.d

The neck shaft angle and the ante version angle are derived by using trigonometric function .

Basic Trigonometric Functions



$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \csc\theta = \frac{\text{hypotenuse}}{\text{opposite}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \sec\theta = \frac{\text{hypotenuse}}{\text{adjacent}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}} \qquad \cot\theta = \frac{\text{adjacent}}{\text{opposite}}$$

In this three dimensional diagram, the geometrical relationship between AP and Lateral view is demonstrated.

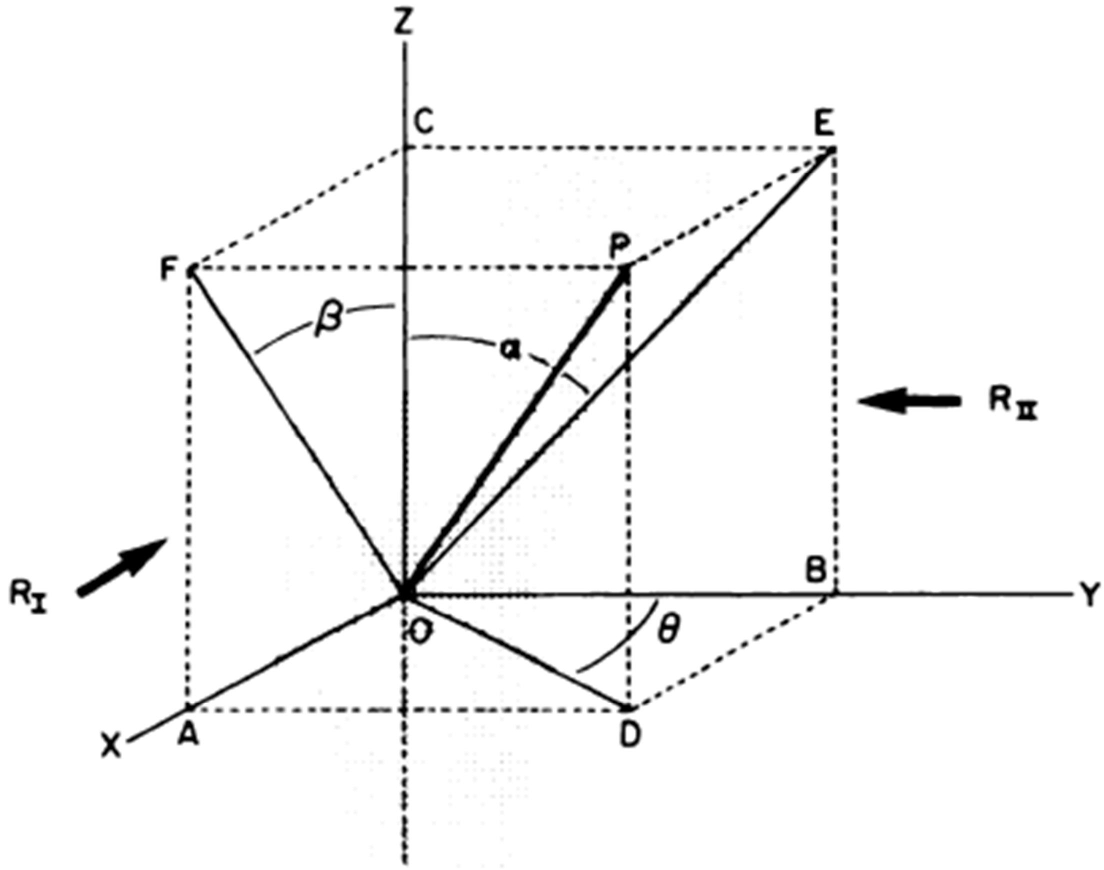


Fig 5.a Describes the geometrical relationship between AP and lateral view of dry femur.

O-P	Axis of femoral neck
R1	Direction of x ray beam in AP view
R2	Direction of x ray beam in lateral view
Y-Z plane	Trans condylar plane
X-Z plane	Saggital plane
X-Y plane	Perpendicular to both Y-Z and X-Z plane

Y-Z plane –contains

1. antero posterior projection of neck axis (OE)
2. Projected cervico femoral angulation (α)

X-Z plane – contains

1. lateral projection of neck axis (OF)
2. Projected cervico femoral angulation (β)

The true angle of ante version θ ,is in X-Y plane. This plane is perpendicular to Y-Z and X-Z plane.

If we de rotate the proximal end of femur to zero degrees, an antero-posterior radiograph can determine the true neck shaft angulation. [34,17.]

In the Fig.5.b the neck axis is de rotated to zero degree ante version and it is represented in the trans condylar plane as OH. True femoral NSA represented by angle $\boldsymbol{\gamma}$**.**

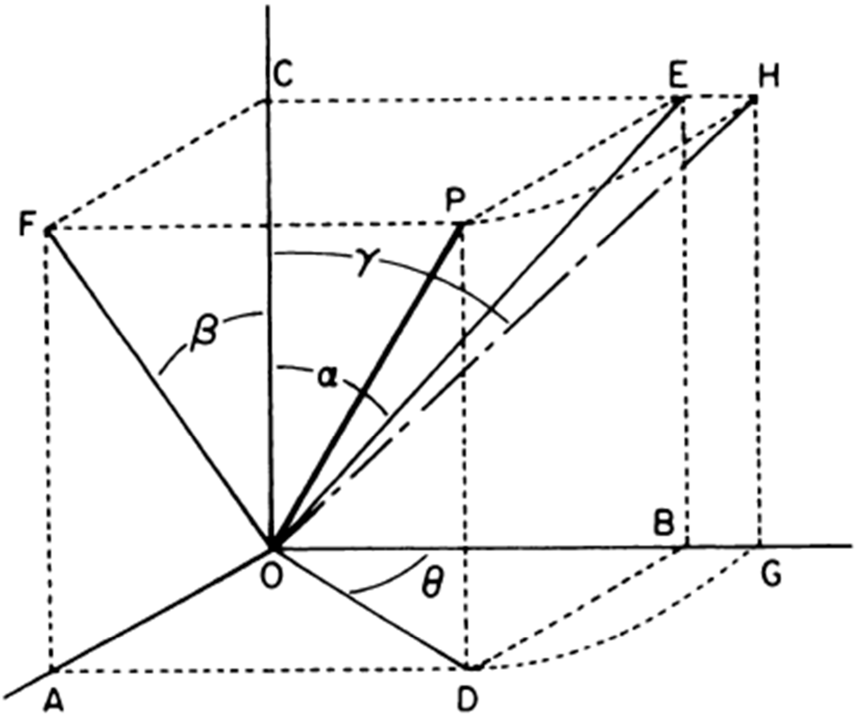


Fig 5.b

Derivation of trigonometric formula:

Geometric relationship between AP and Lateral radiography. Fig.5.b

tan θ =BD / OB =CF / CE

= OC tan β / OC tan α

= tan β / tan α

Geometric relation between ante version and cervico femoral angulation:

$$\tan \gamma = CH / OC$$

$$= OD / CE \cot \alpha$$

$$= OB \operatorname{Cosec} \theta / CE \cot \alpha$$

$$= \operatorname{Cosec} \theta / \cot \alpha$$

$$= \tan \alpha / \cos \theta$$

Since the usage of trigonometric function and calculation is complicated , a simple method developed by dynamically illustrating the projected angles in the essential 3 planes opening out it in a single plane.[17]

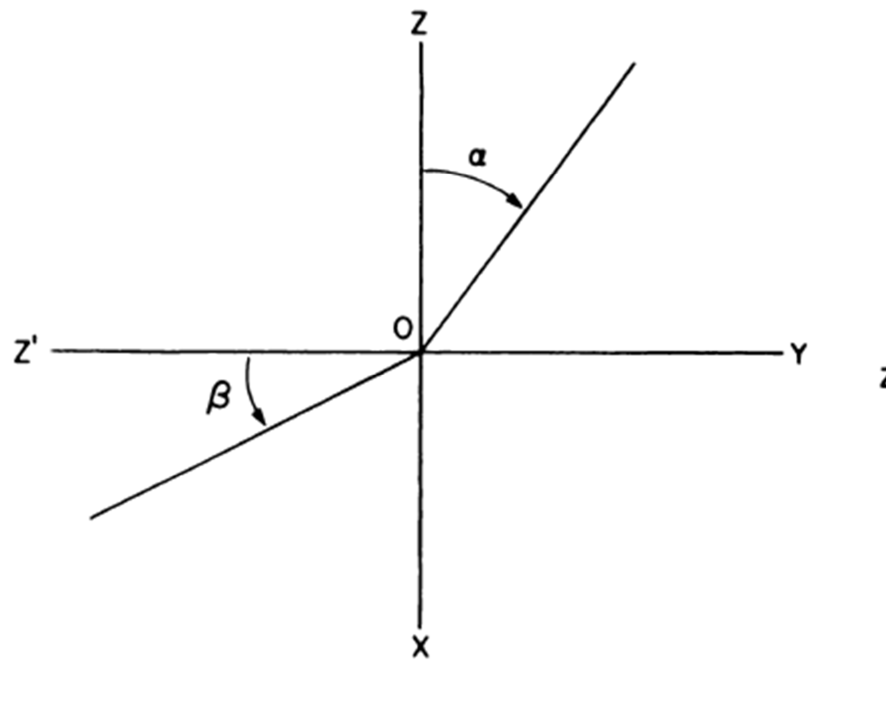


Fig 5.c: Demonstrates the projected angles in three essential planes.

α angle is the projected angle of AP view in right upper quadrant (Z_Y) plane which is the trans condylar plane. β angle is the projected angle of lateral view in left lower quadrant (X_Z') plane which is the saggital plane.

Draw horizontal axis YZ' and XZ vertical axis , both intersect at right angles. A line rotated clock wise from OZ axis is the angle α. A line rotated counter clockwise from OZ' is the angle β.

From point C in OZ axis ,a horizontal line CE parallel to the axis OY is drawn.Then a point C' on OZ' axis is taken so that OC = OC' and a vertical line C'F parallel to the axis OX is drawn.

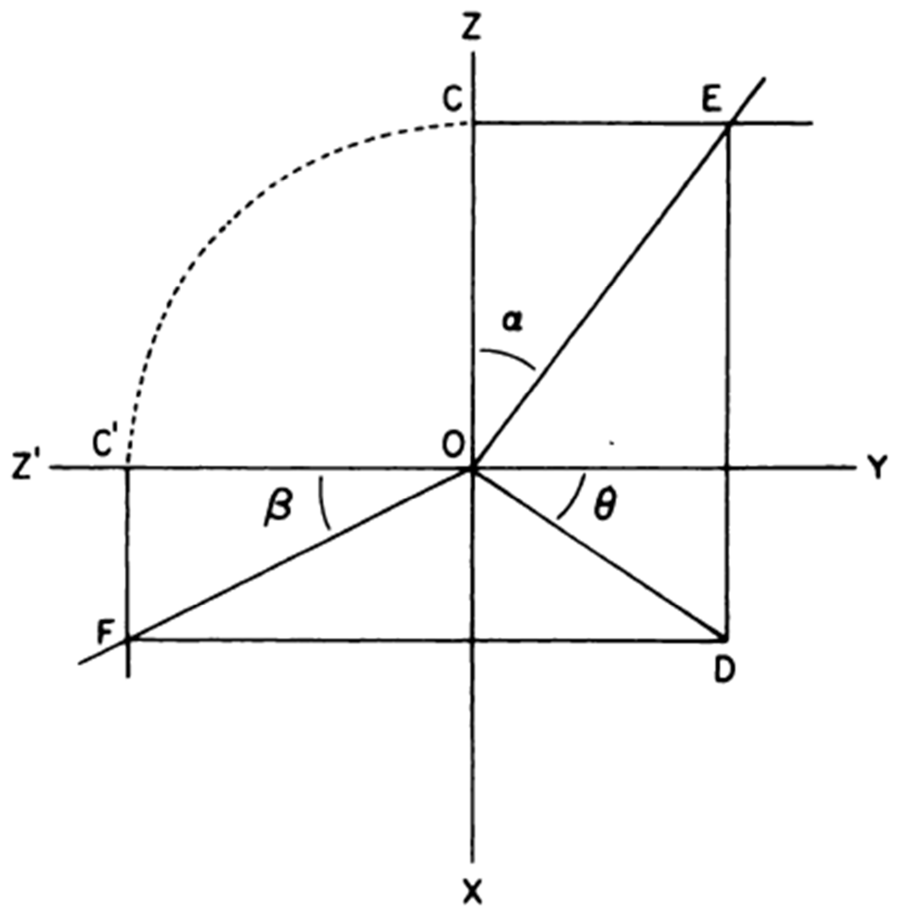


Fig 5.d: Demonstrates the projected angles and the derived angles in three essential planes.

A horizontal line from F and a vertical line from E is drawn and the point of intersection D on the X - Y plane . The degree of femoral neck anteversion is represented by the angle DOY.

$\tan \theta = \tan \beta / \tan \alpha$

The true cervico femoral angulation can be determined by derotating OD to the axis OY .Determine G so that OD = OG. A vertical line GH is drawn. By derotation the distance BE is not affected. The true cervico femoral angulation γ is represented by the angle HOZ.

$\tan \gamma = \tan \alpha / \cos \theta$

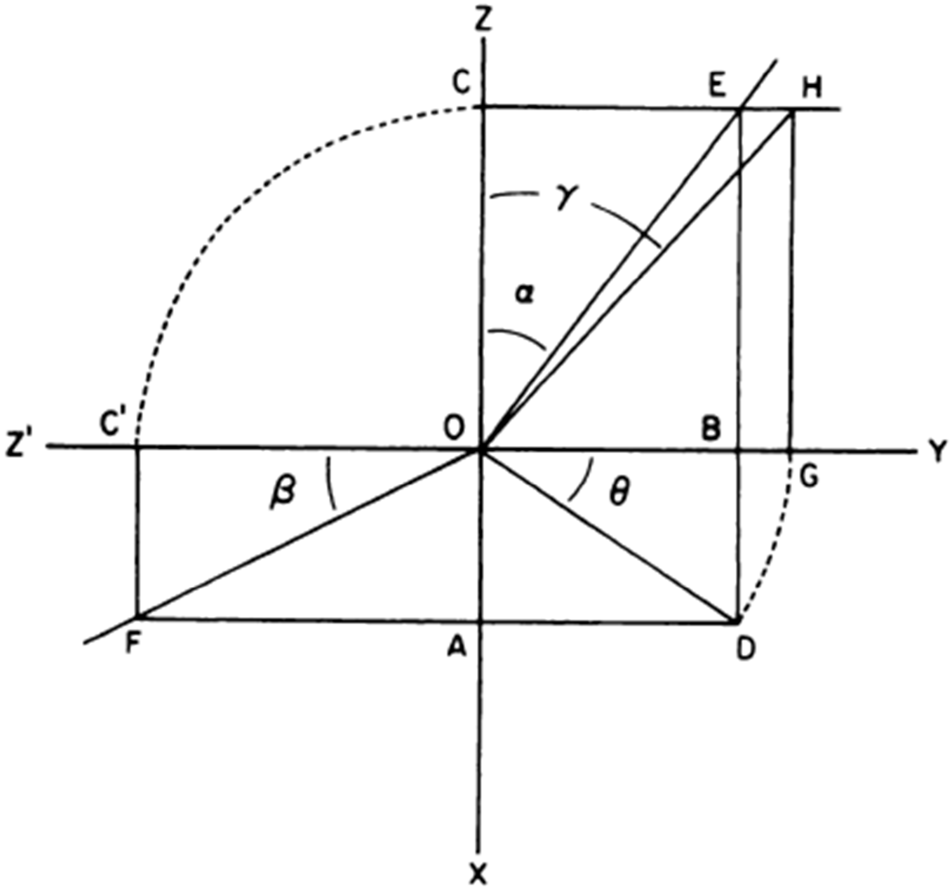
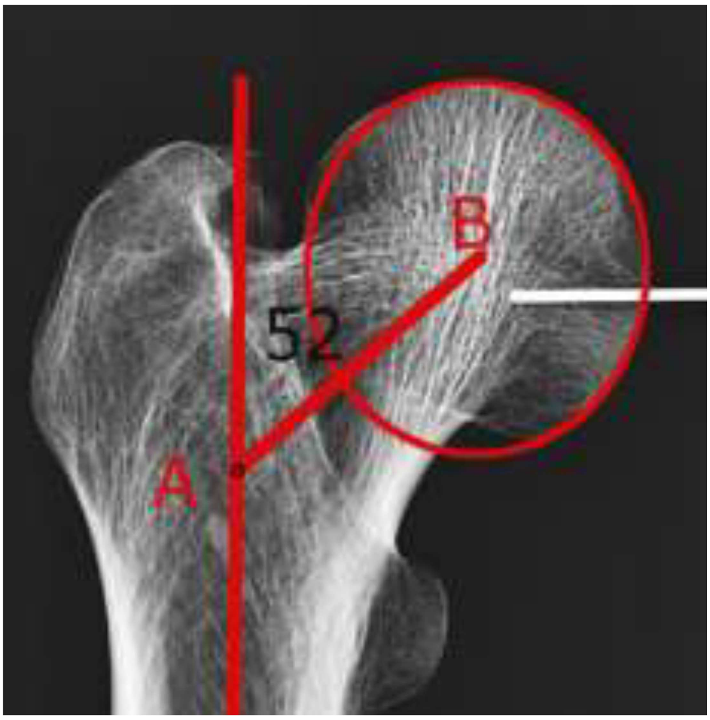
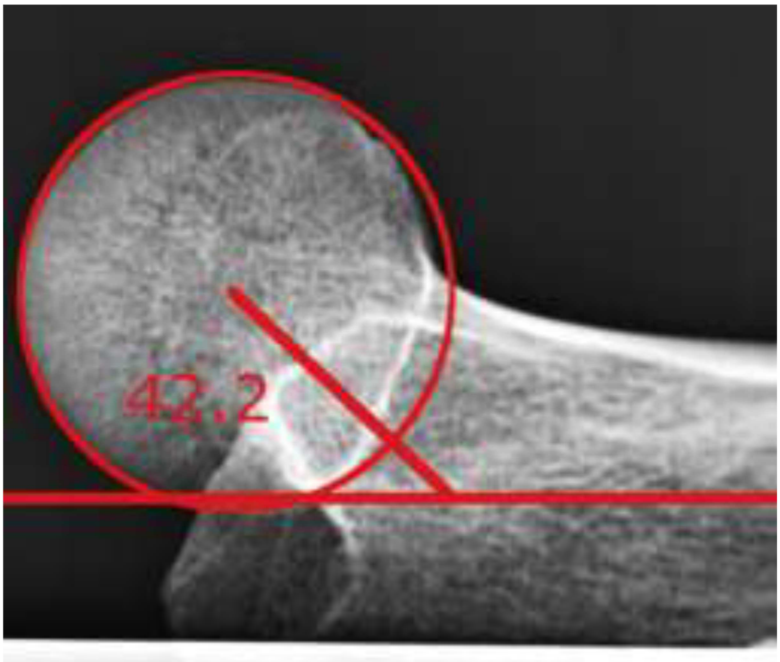


Fig 5.e: Demonstrates the projected angles and the derived angles in three essential planes.

For example



NECK-SHAFT ANGLE IN AP VIEW



NECK SHAFT ANGLE IN LATERAL VIEW

$\alpha = 52° ; \beta = 42.2°$

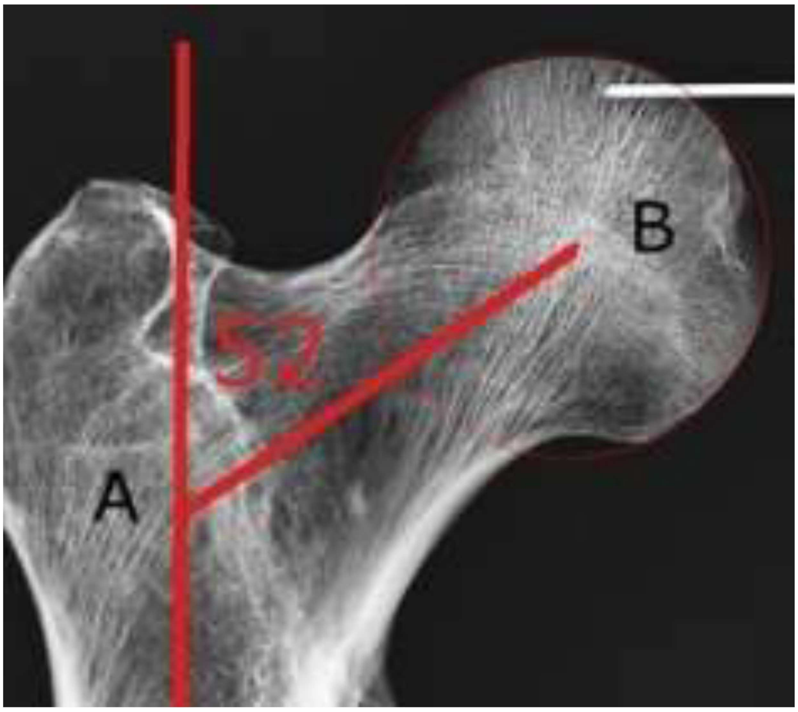
$\tan \theta = \tan \beta / \tan \alpha$

$= \tan 42.2° / \tan 52°$

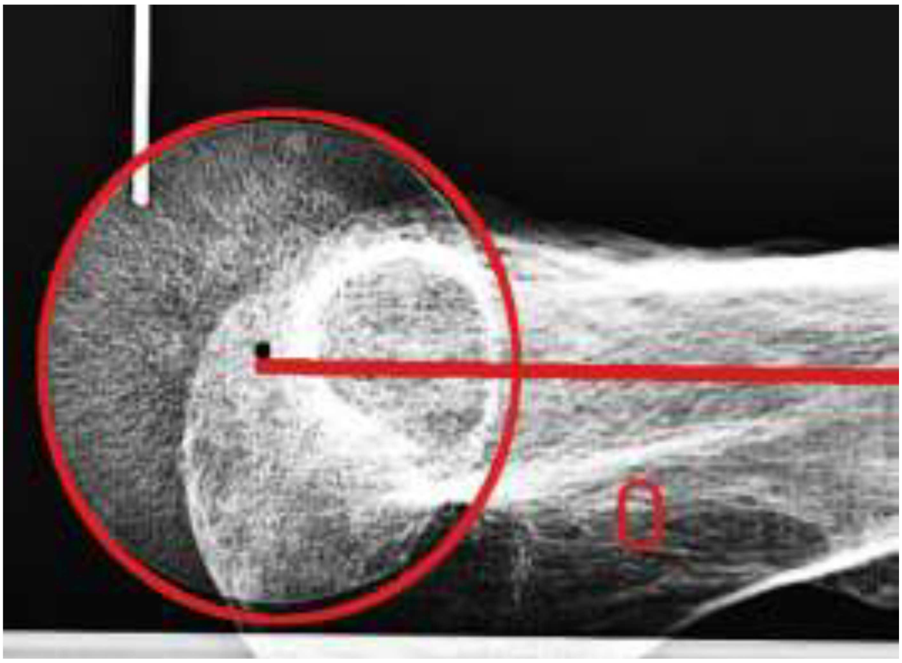
$= 0.708$

$\Theta = 35.3°$

BIPLANAR METHOD : Neutral version

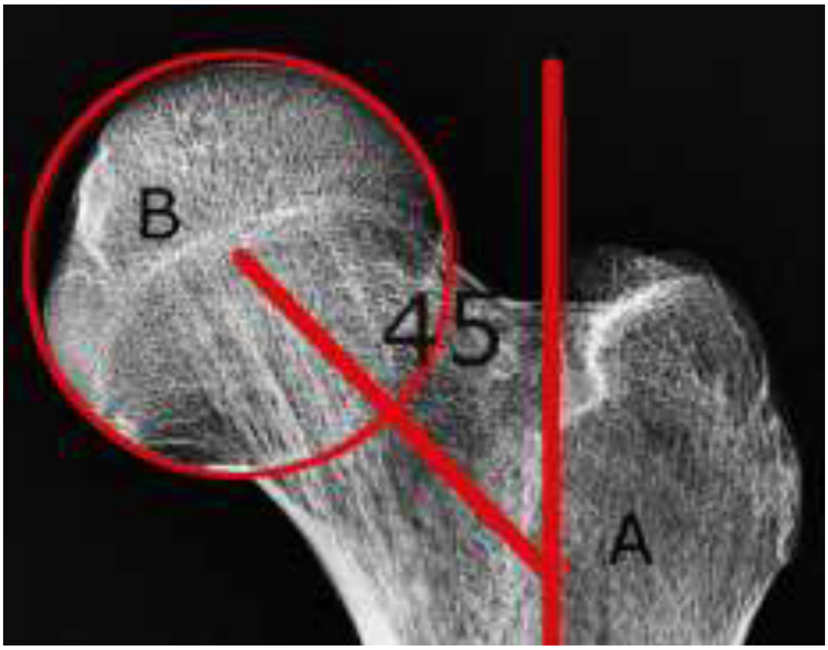


A P view

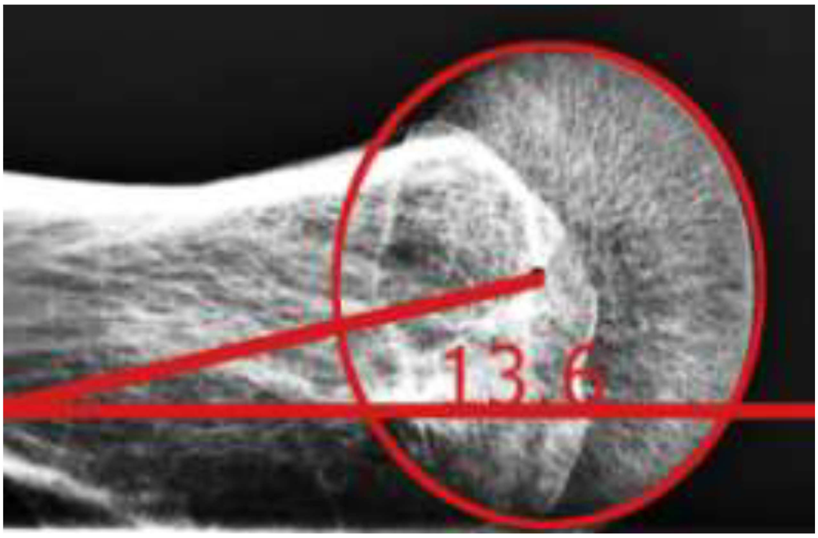


Lateral View

BIPLANAR METHOD : RETROVERSION



AP View

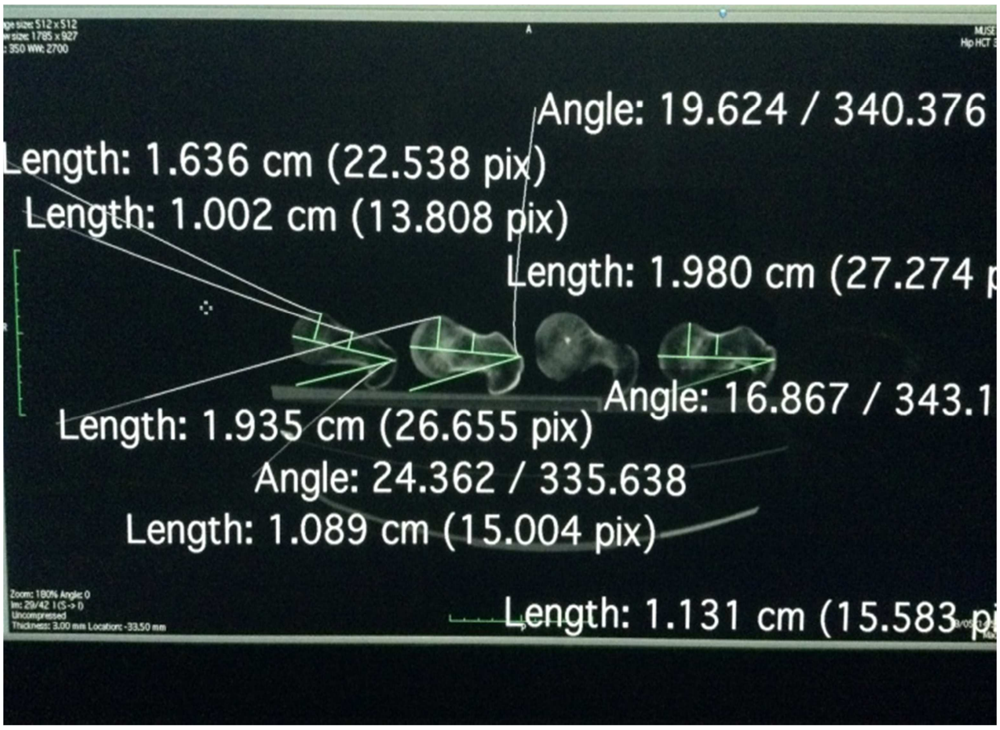


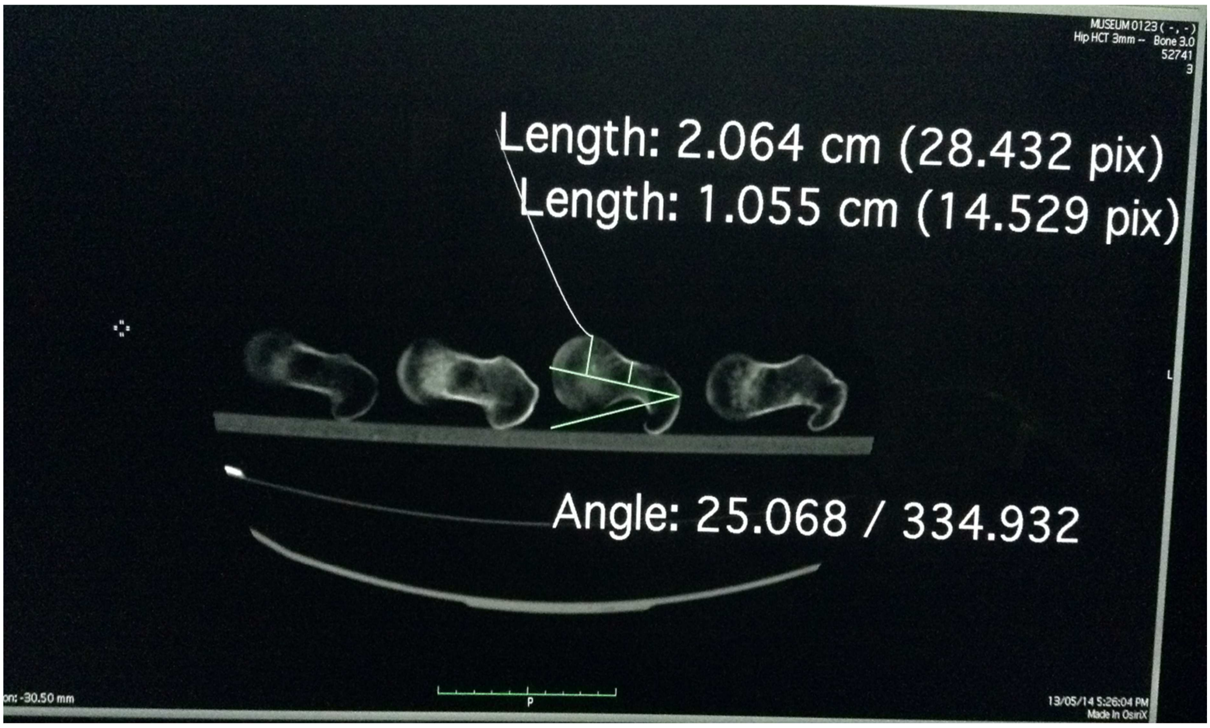
Lateral View

Axial computed tomography:

Anteversion angle : In our study CT measurements was done in concurrence with the Institute of Radiology.

The CT measurements were taken by placing the dry femur over parallel surface . 5mm cuts perpendicular to the axis of the femoral shaft made in the proximal third of the femur up to the level of lesser trochanter. Distal femoral cuts were made in 5mm thicknesss perpendicular to the femoral condyles and axis of the femoral shaft. The proximal femur cut that best revealed the alignment of femoral head and neck was chosen to measure the neck –horizontal angle(NH).[8,35,36.]

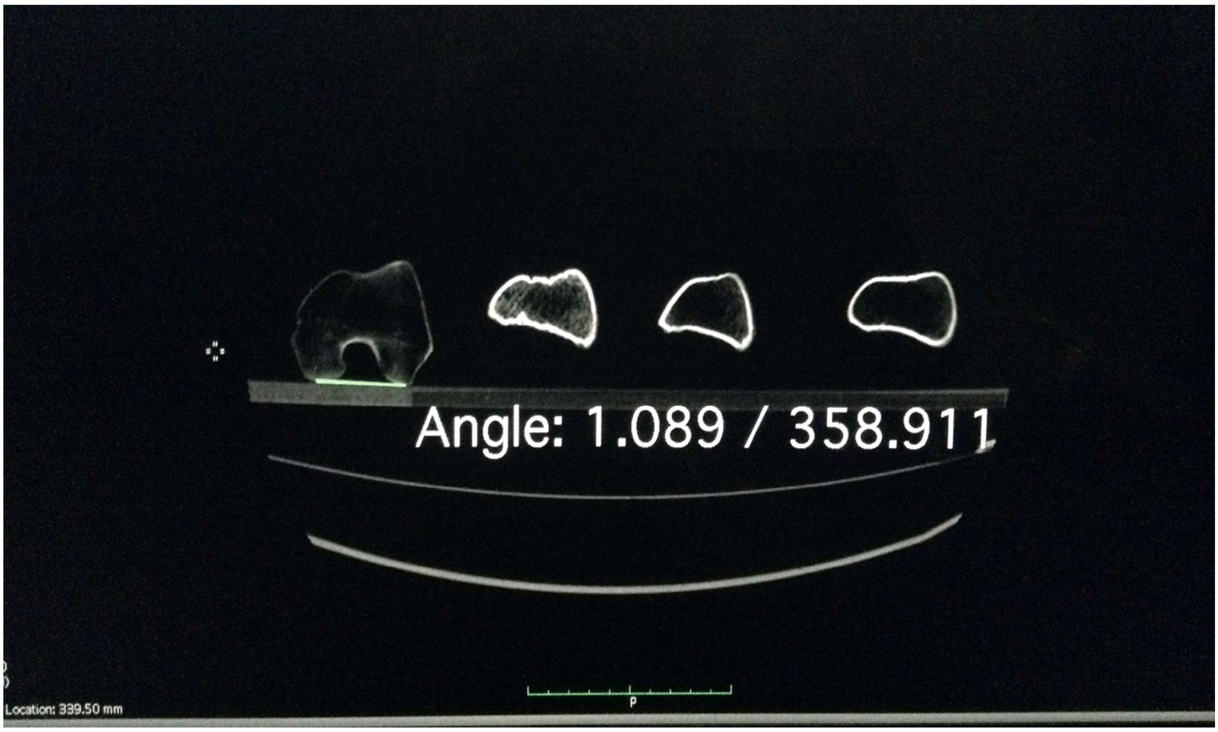




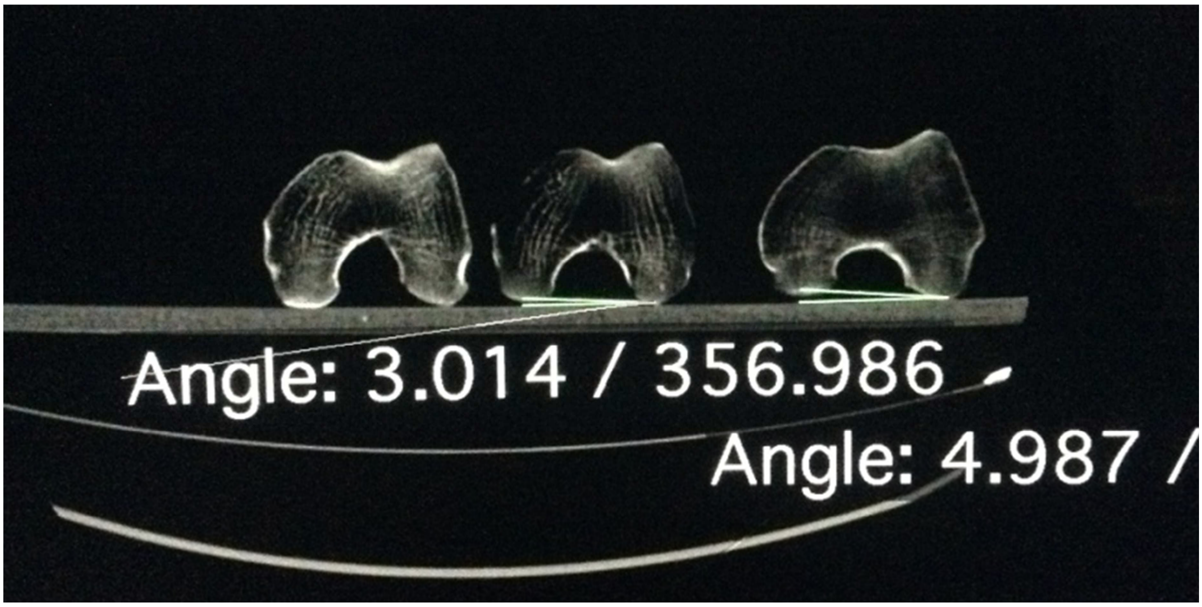
Describes the neck horizontal angle

The distal femur cuts that best revealed the femoral condyles was chosen to measure the condyle – horizontal angle(CH).[8,20,35,36,37] The femoral neck anteversion angle was measured in relation to condylar axis of the femur.i.e

Femoral anteversion = Neck horizontal angle – condyle horizontal angle.



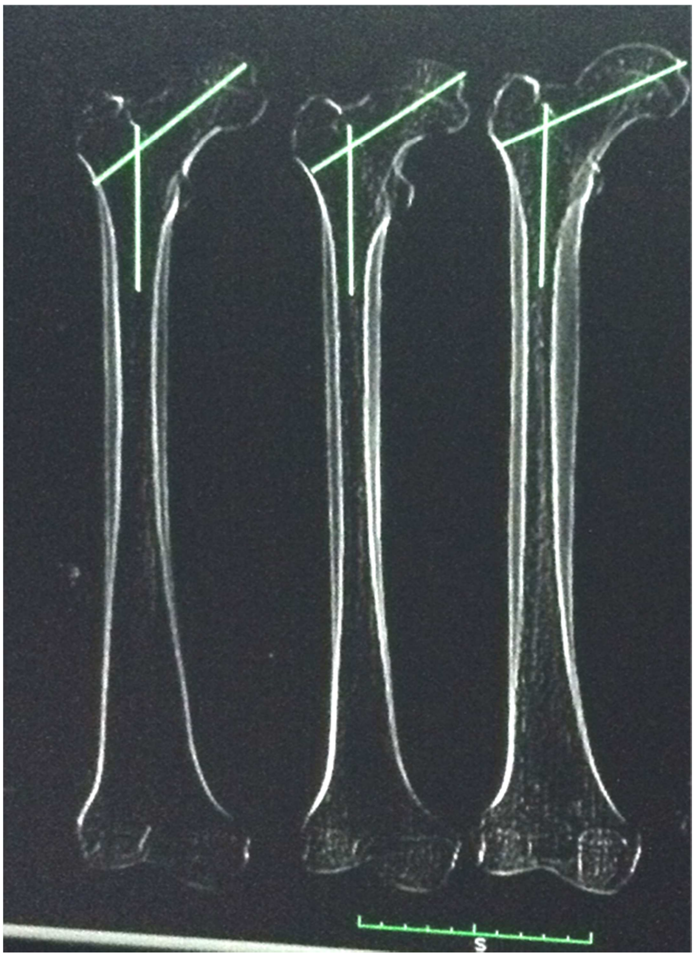
Describes the trans condylar axis



Describes the condylar horizontal angle

CT-Neck shaft angle

The dry femur was placed on parallel surface. CT scannogram of the entire femur was taken. The centre of femoral head and the midpoint of the base of the femoral neck was marked.The line joining the two points was taken as the femoral head neck axis. At the level of lesser trochanter the mid point of the femoral shaft was marked and the line extended proximally and distally. This was taken as the femoral shaft axis. The angle formed between the femoral head –neck axis and the femoral shaft axis was taken as the neck shaft angle of the particular dry femur.

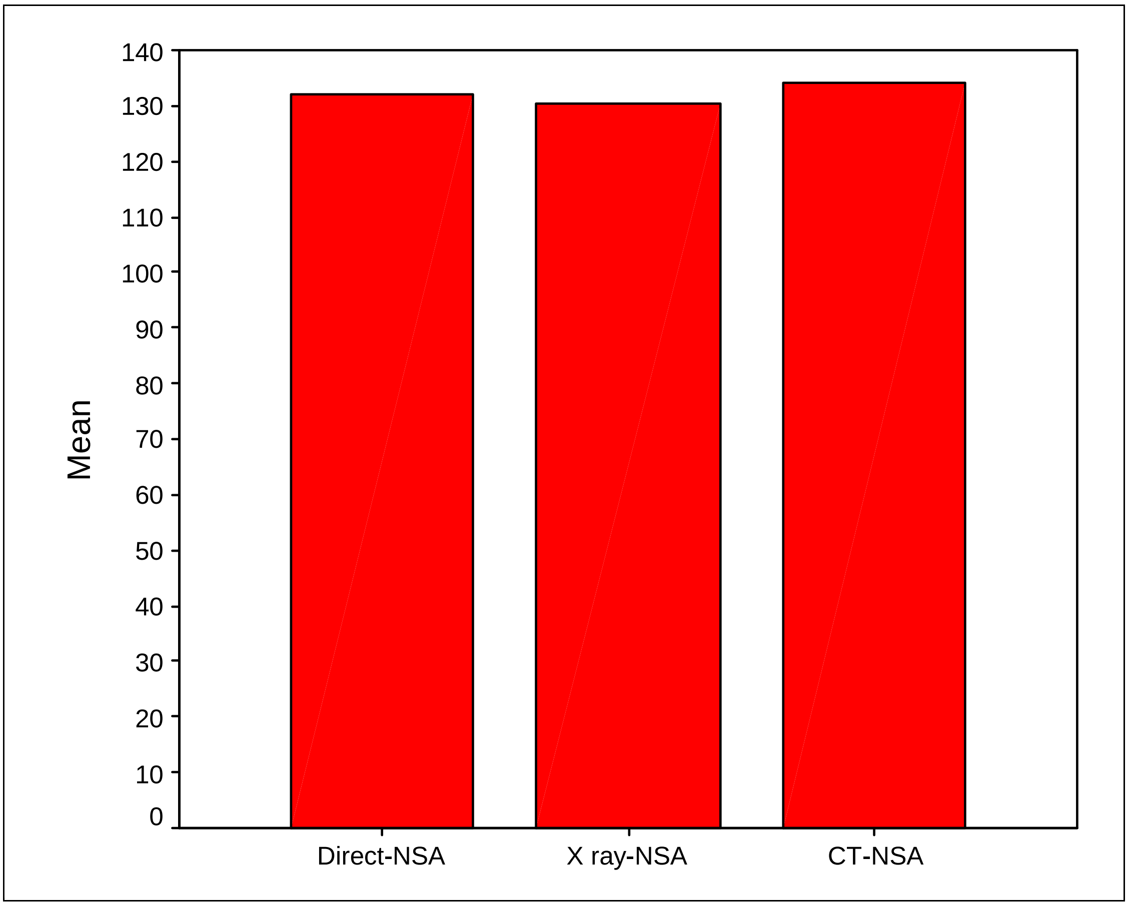


Describes the NSA measurement in CT

RESULTS

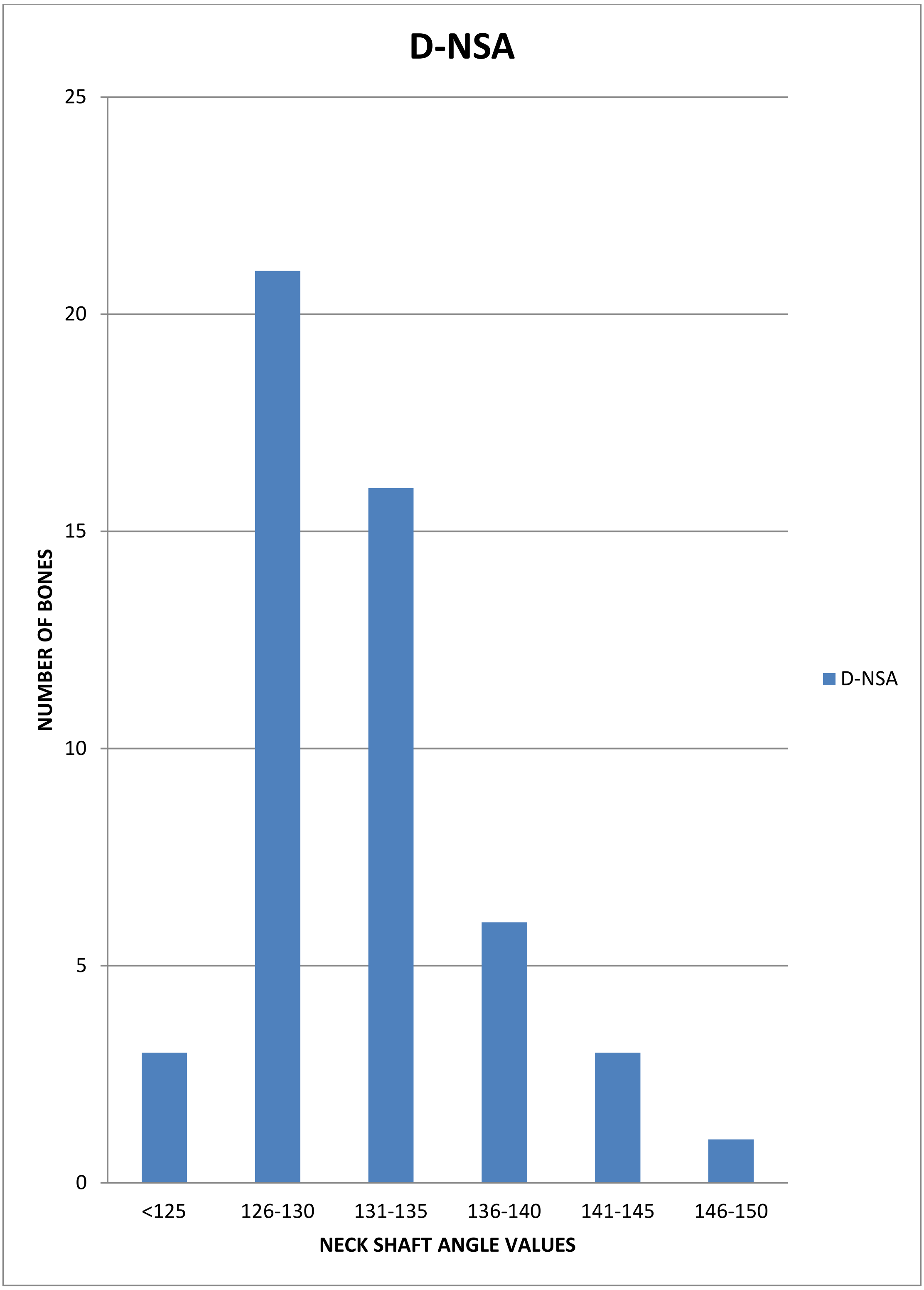
Results of neck shaft angle measurement:

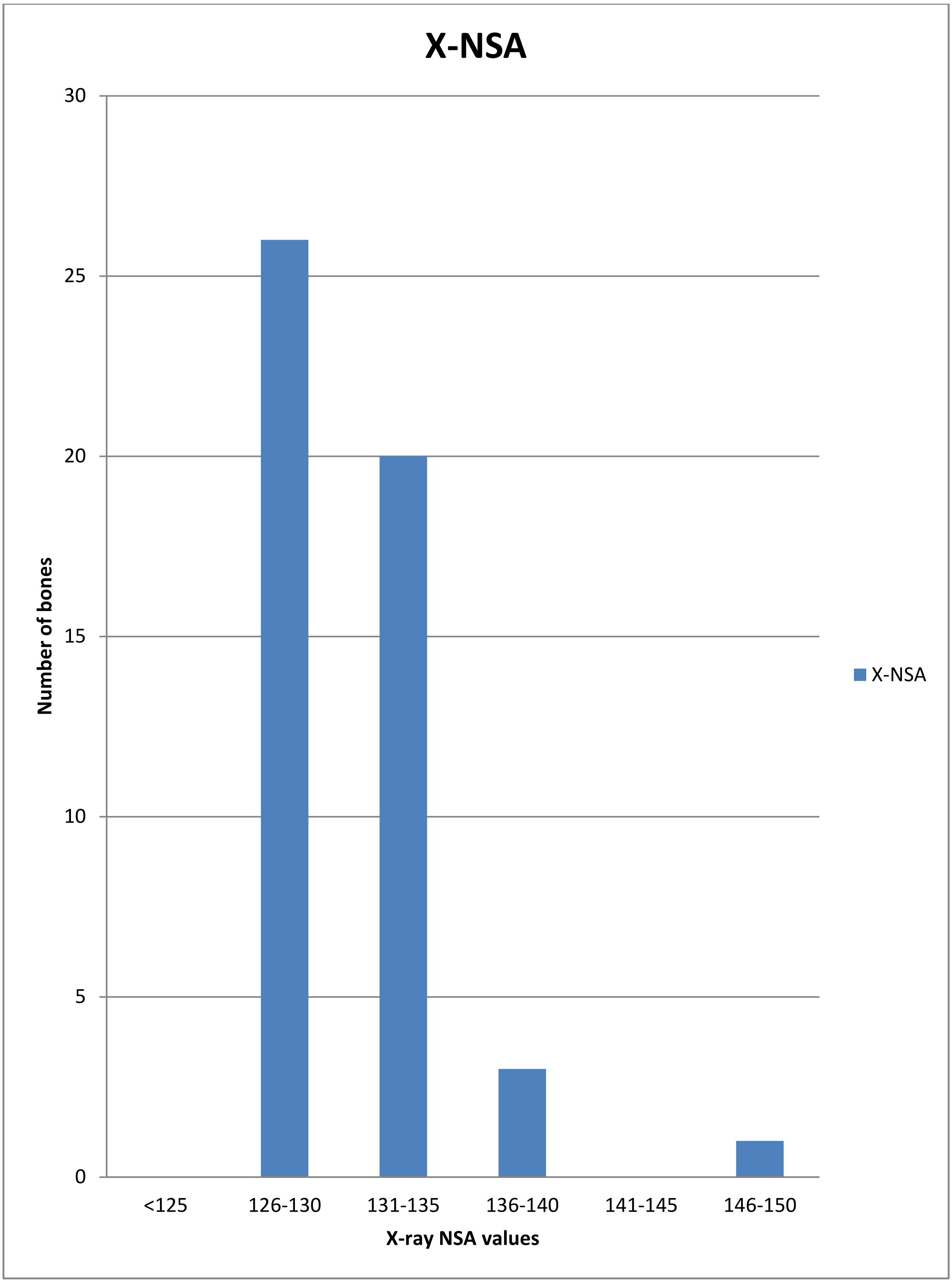
BAR DIAGRAM

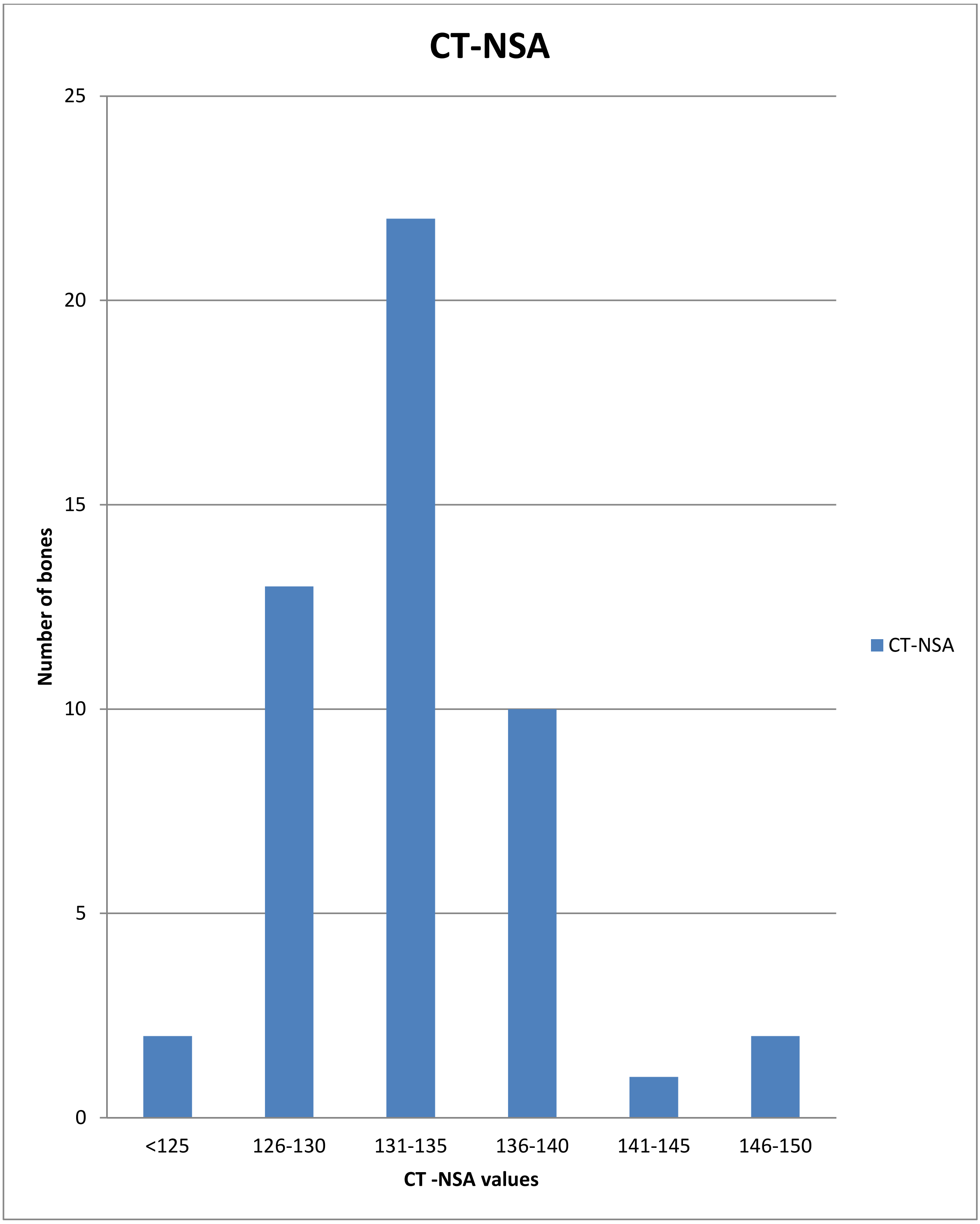


NPar Tests:

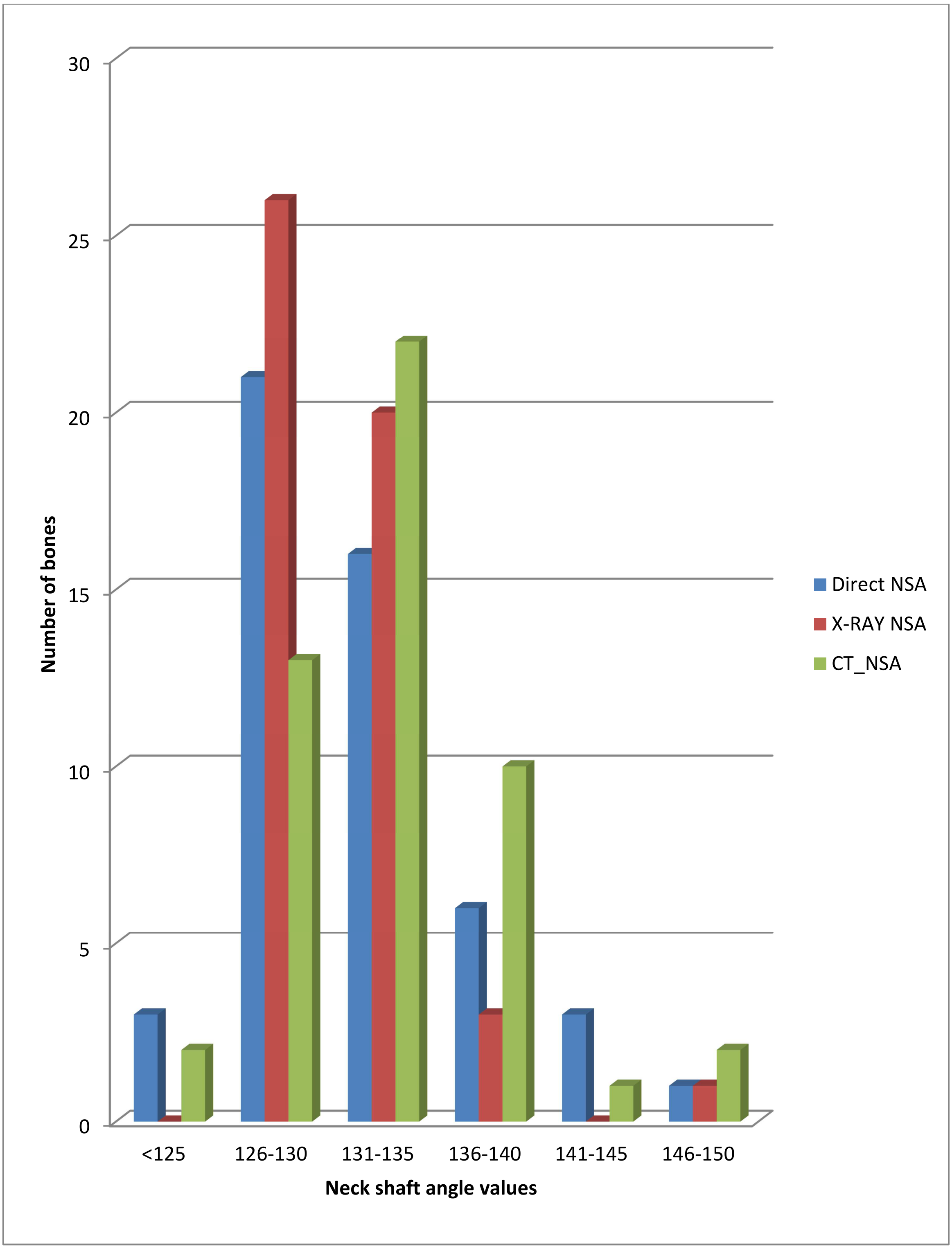
NPAR TESTS performs nonparametric tests. Non parametric tests make very few assumptions about the distribution of the data. One or more tests may be specified by using the corresponding subcommand. If the statistics subcommand is also specified, then summary statistics are produces for each variable that is the subject of any test.


D-NSA
25
20
15
10
5
0
NUMBER OF BONES
<125
126-130
131-135
136-140
141-145
146-150
NECK SHAFT ANGLE VALUES
D-NSA


X-NSA
30
25
20
15
10
5
0
Number of bones
<125
126-130
131-135
136-140
141-145
146-150
X-ray NSA values
X-NSA



Comparison of direct, x-ray and CT measurement of NSA



30
25
20
15
10
5
0
Number of bones
<125
126-130
131-135
136-140
141-145
146-150
Neck shaft angle values
Direct NSA
X-RAY NSA
CT_NSA

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Direct-NSA	50	131.94	5.332	123	148
X ray-NSA	50	130.30	4.082	124	147
CT-NSA	50	133.928	5.0109	125.1	148.7

Table 1.1 –**Describes the measurements of neck shaft angle by Direct,Xray and CT methods .**

Friedman Test

Ranks

	Mean Rank
Direct-NSA	1.89
X ray-NSA	1.45
CT-NSA	2.66

Table 1.2 X ray method of Neck shaft angle measurement was observed to be the accurate one among the three methods.

The **Friedman test** is a non-parametric statistical test developed by the U.S. economist Milton Friedman. It is used to detect differences in treatments across multiple test attempts. The procedure involves ranking each row (or *block*) together, then considering the values of ranks by columns.

T-Test

Group Statistics

	Side	N	Mean	Std. Deviation	Std. Error Mean
Direct-NSA	Left	22	130.73	5.284	1.127
	Right	28	132.89	5.266	.995
X ray-NSA	Left	22	129.77	2.861	.610
	Right	28	130.71	4.845	.916
CT-NSA	Left	22	132.622	4.6017	.9811
	Right	28	134.954	5.1591	.9750

Table 1.3 Describes the group statistics of the study.No significant difference observed between left and right femur in all the three methods.

Standard Error of the Mean

$$SE_{M_x} = \frac{\sigma}{\sqrt{N}}$$

This equation implies that sampling error decreases as sample size increases. This is important because it suggests that if we want to make sampling error as small as possible, we need to use as large of a sample size as we can manage. Technically, the SE is also called a **68% confidence interval**. By extension, we can say that 68% of sample means will fall between – 1 SE and + 1 SE.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean	P value
Pair 1	Direct-NSA	131.94	50	5.332	.754	0.001**
	X ray-NSA	130.30	50	4.082	.577	
Pair 2	Direct-NSA	131.94	50	5.332	.754	<0.001**
	CT-NSA	133.928	50	5.0109	.7086	
Pair 3	X ray-NSA	130.30	50	4.082	.577	<0.001**
	CT-NSA	133.928	50	5.0109	.7086	

Note: ** Denotes significant at 1% level

Table 1.4 :No statistical significance noted between the measurements of neck shaft angle by all the three methods.

SCATTER PLOT

Direct measurement of NSA vs CT-NSA

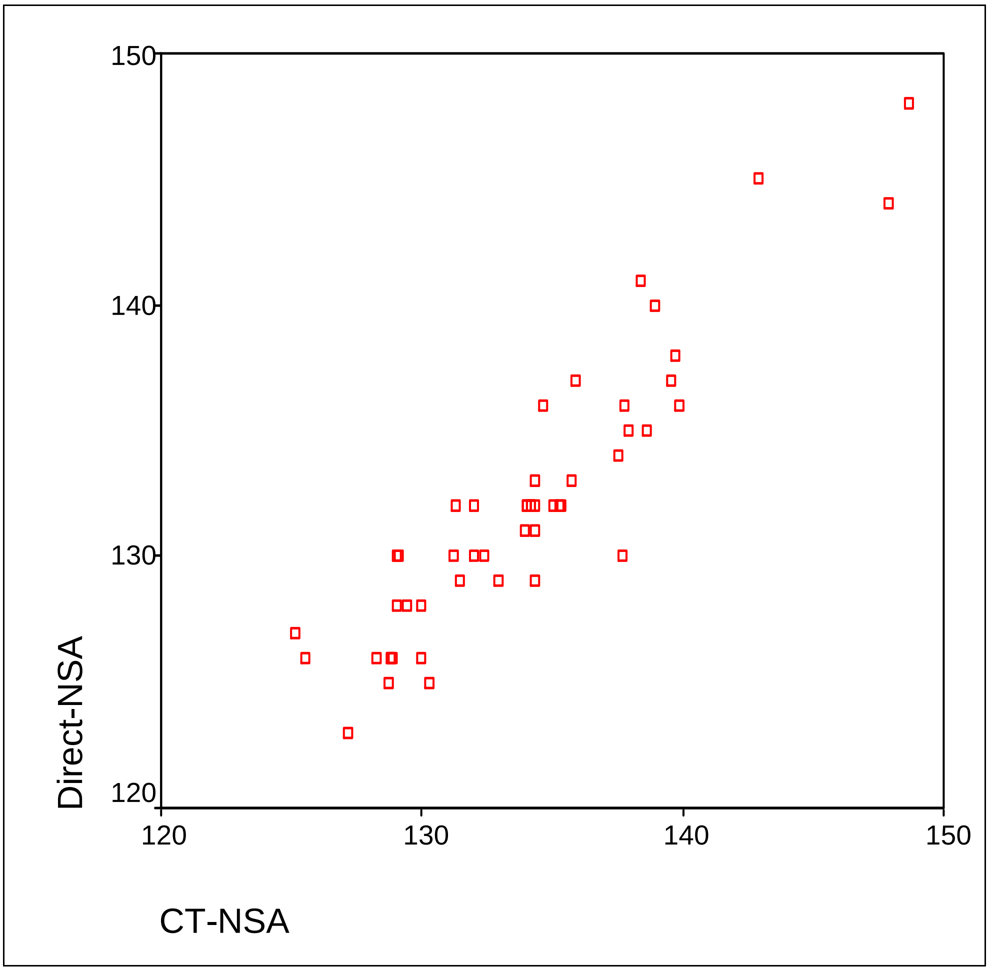


Fig 6.a   Describes the correlation between direct and CT guided measurements of neck shaft angle

SCATTER PLOT

X-NSA vs CT-NSA

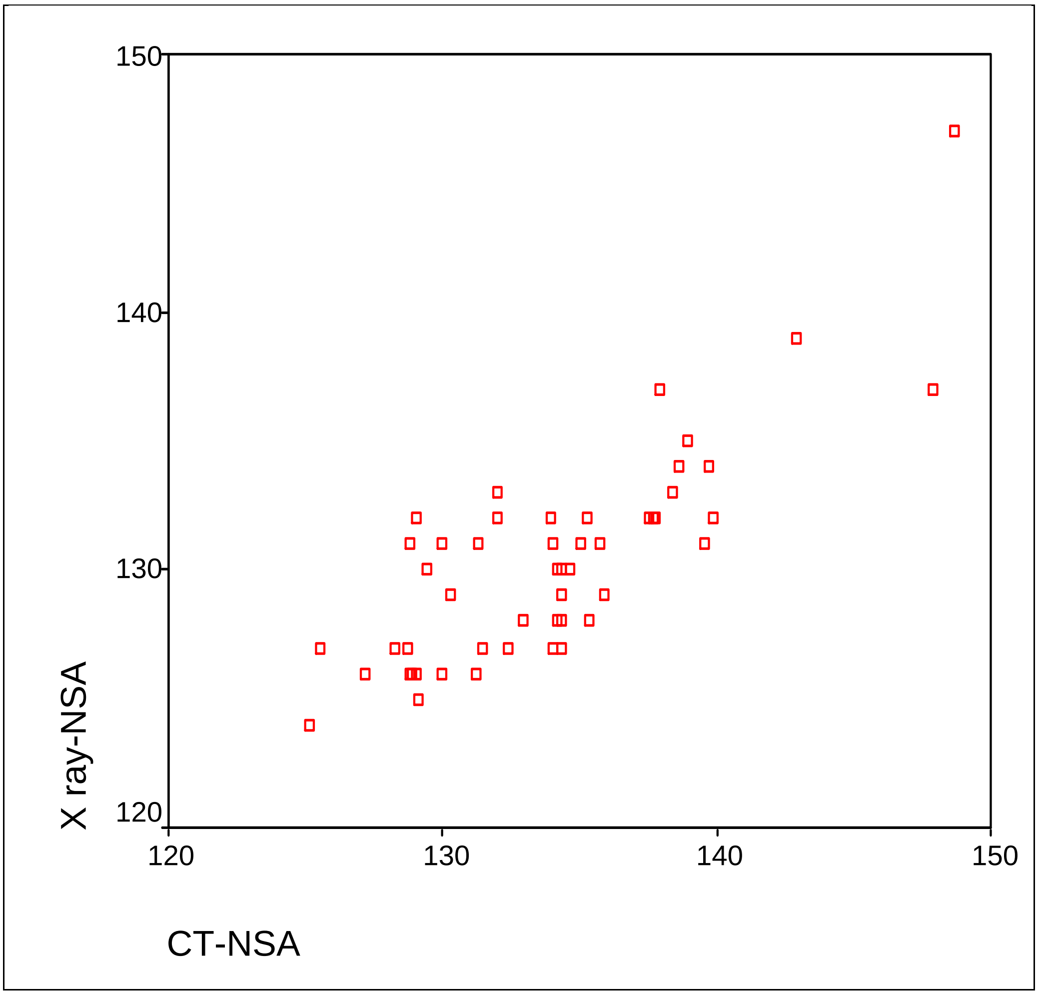


Fig 6.b Describes the correlation between X-ray and CT guided measurements of neck shaft angle.

SCATTER PLOT

Direct measurement –NSA v s   X-ray NSA

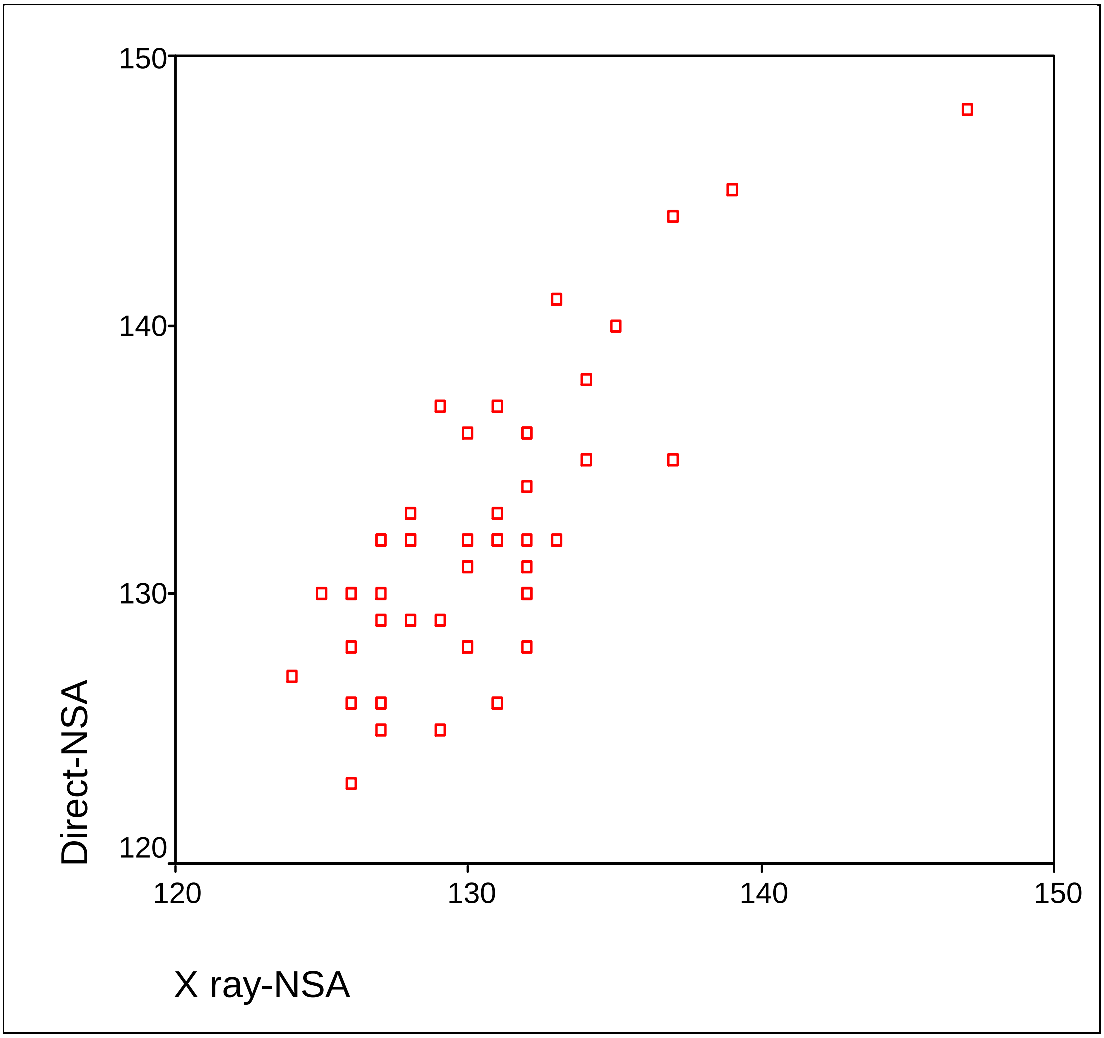
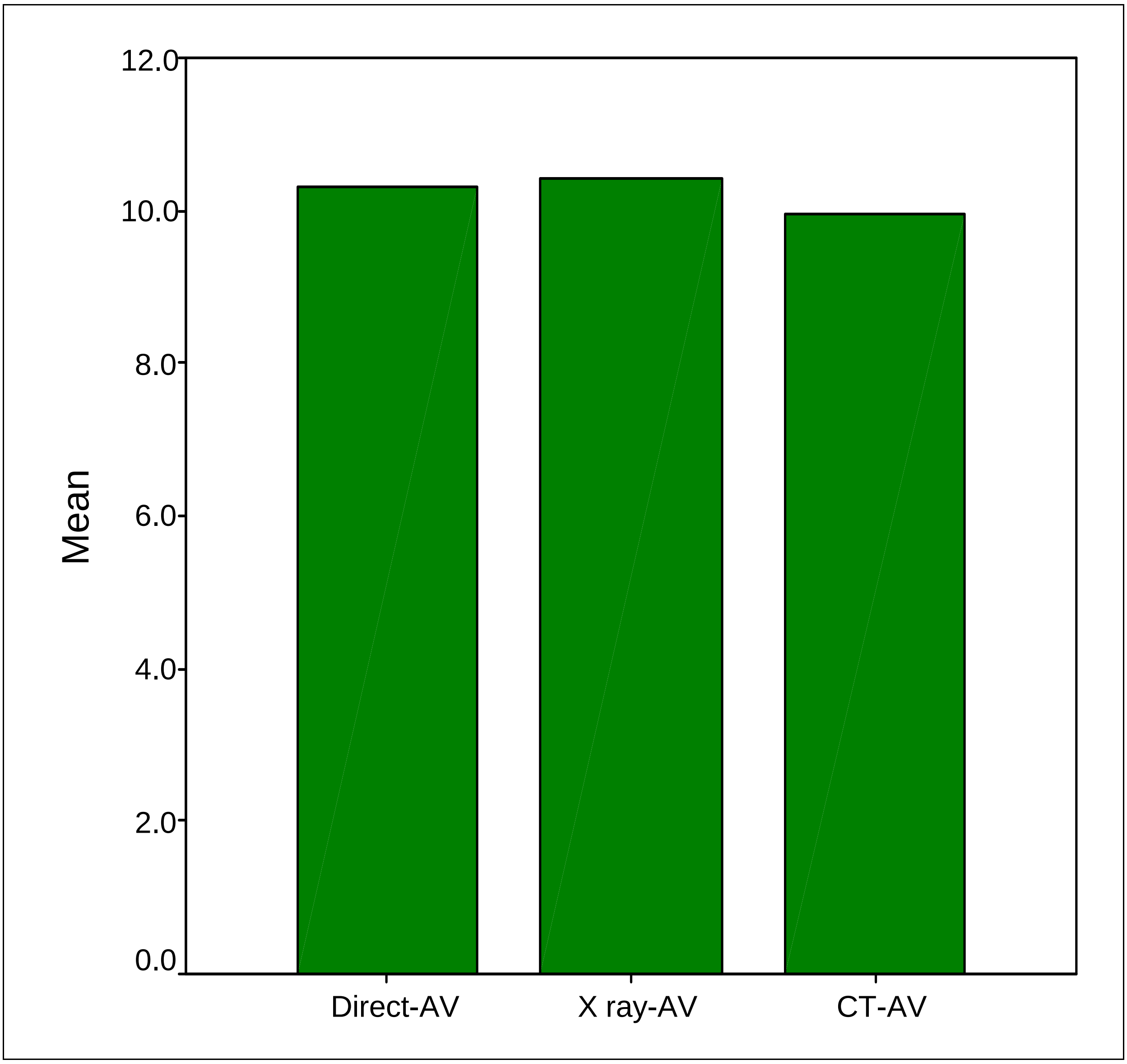


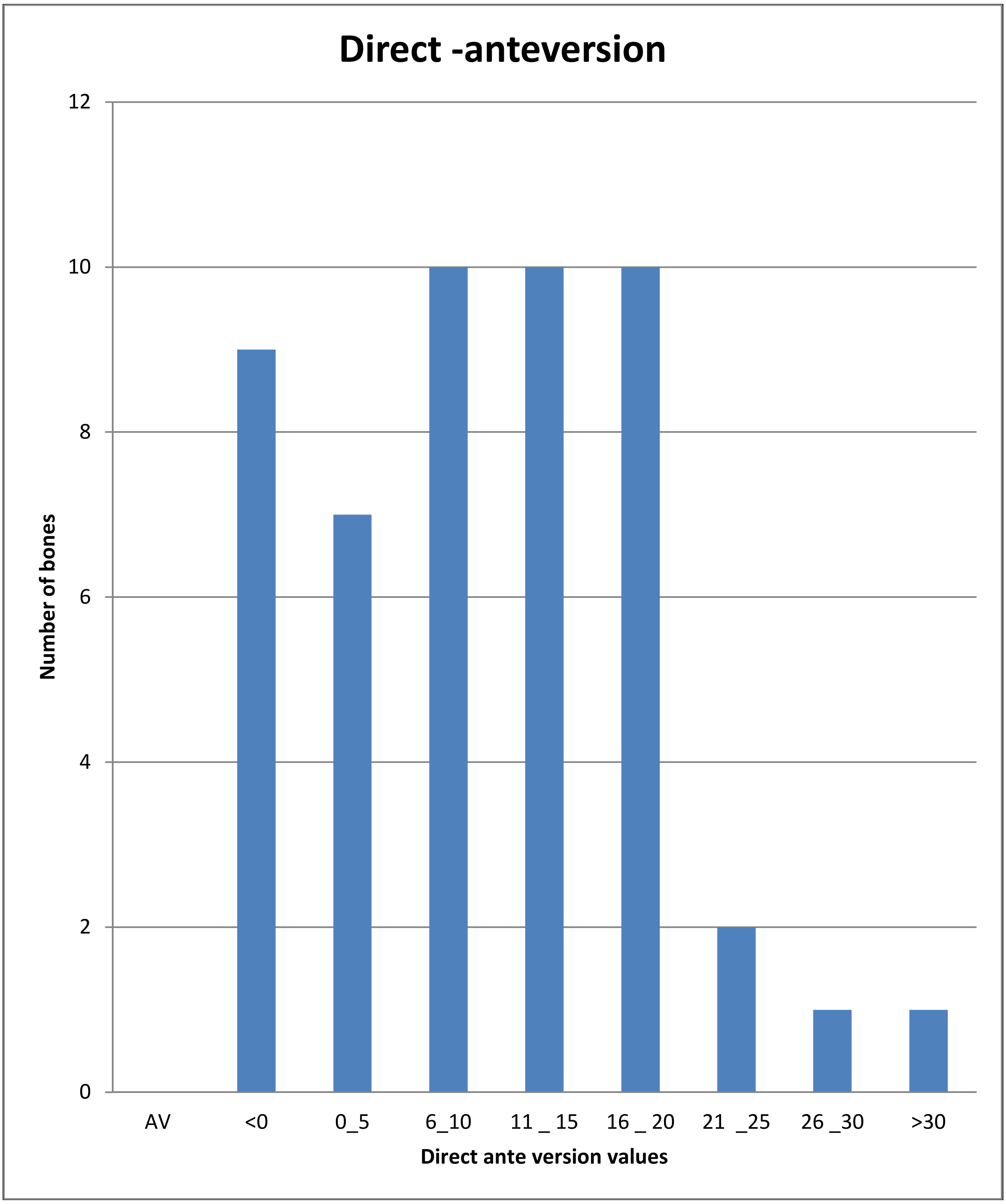
Fig 6. C Describes the correlation between direct and X-ray measurements of neck shaft angle.

The mean neck shaft angle by Direct, X-ray and CT measurements was found to be 131.9± 5.3, 130.3±4, 133.9±5 respectively. Among the three methods the X-ray method seems to be more accurate to measure the neck shaft angle by Friedman test result. There was no significant difference between right and left side bones. The paired T-test reports no statistical significance in all possible three pairs of measurements with a p value of <0.001 (significant with 1% level).The standard error of mean was $<1^{\circ}$ with direct measurements as the reference value.

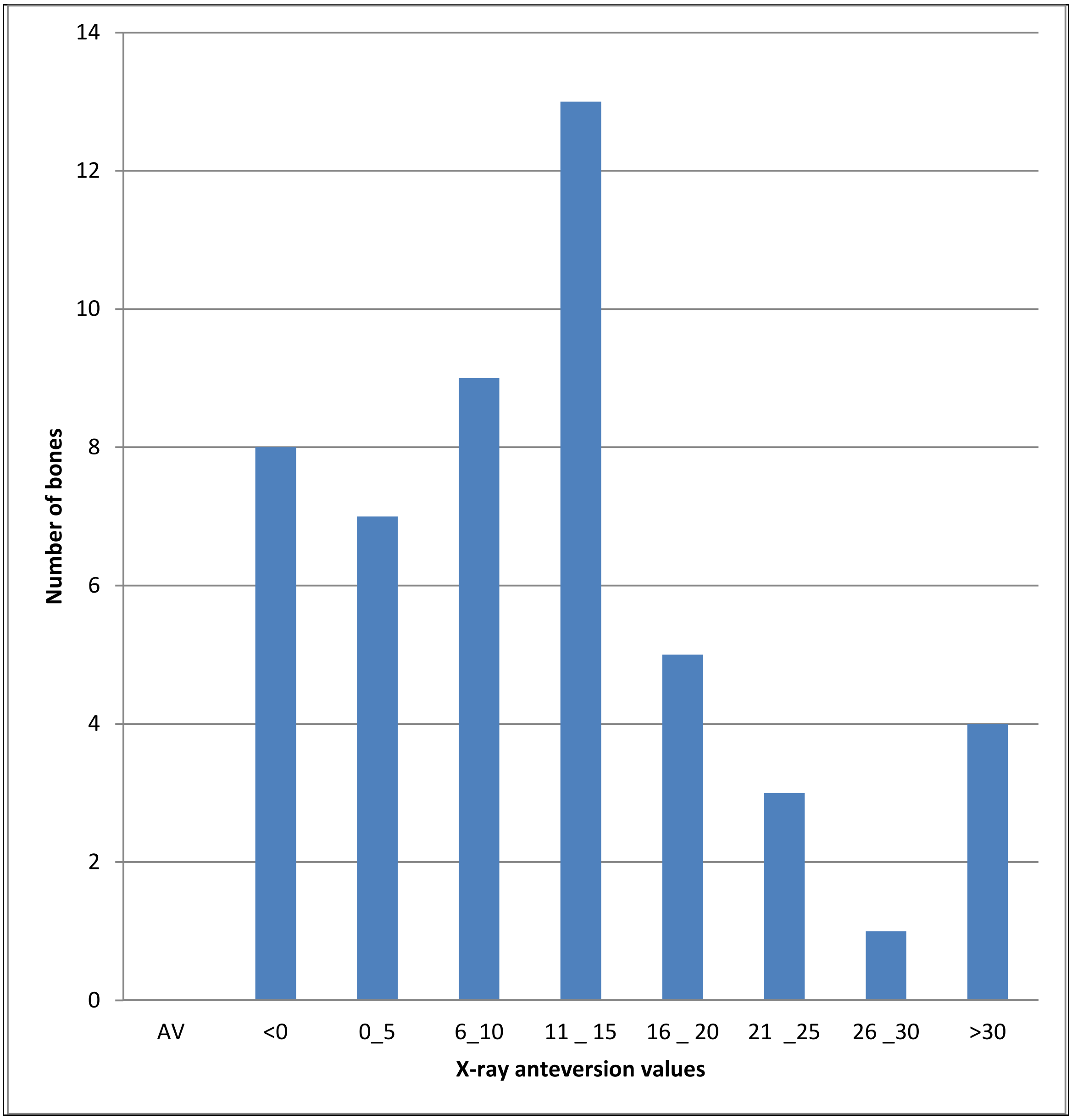
Results of anteversion measurements in dry femur

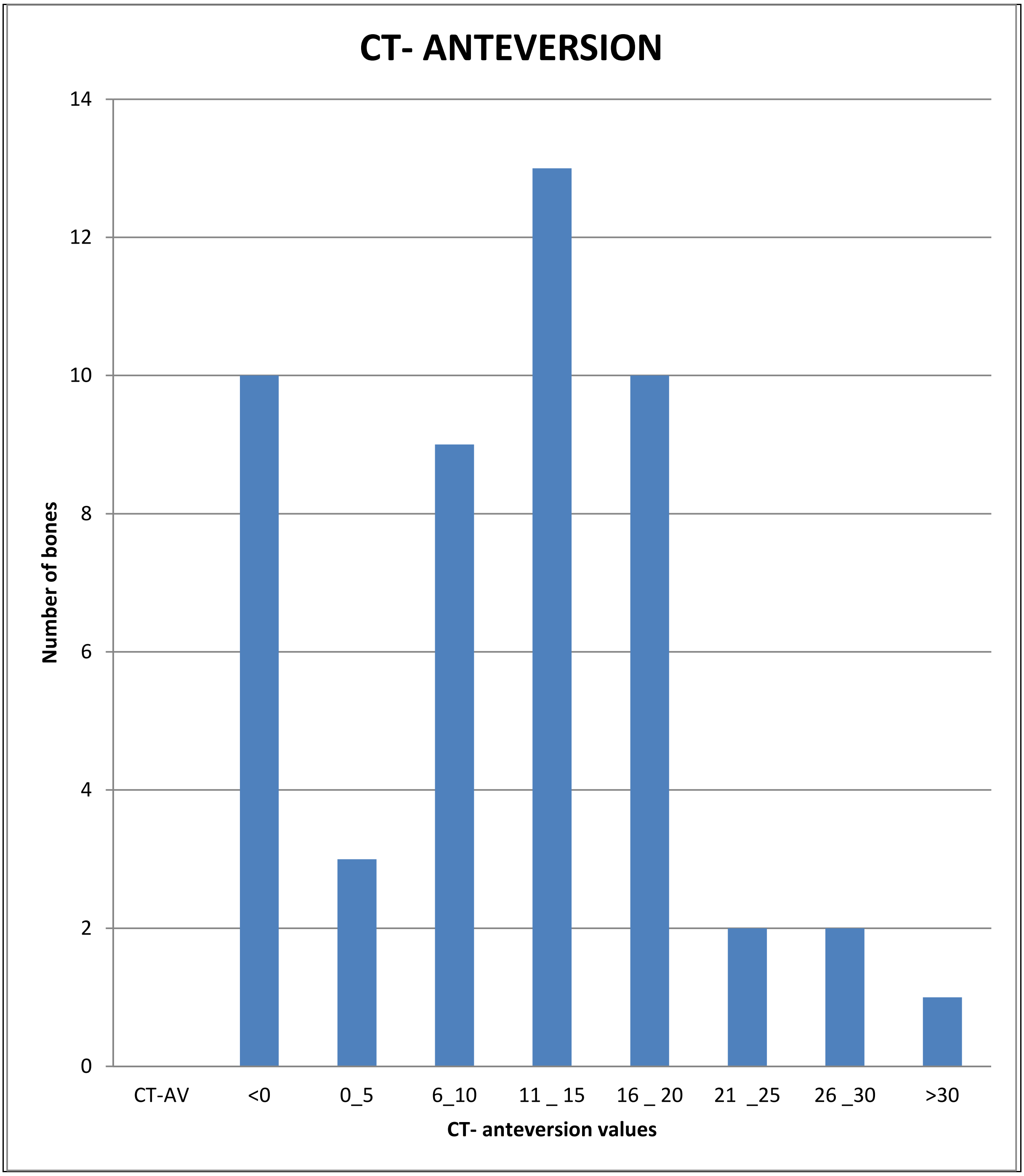
BAR DIAGRAM



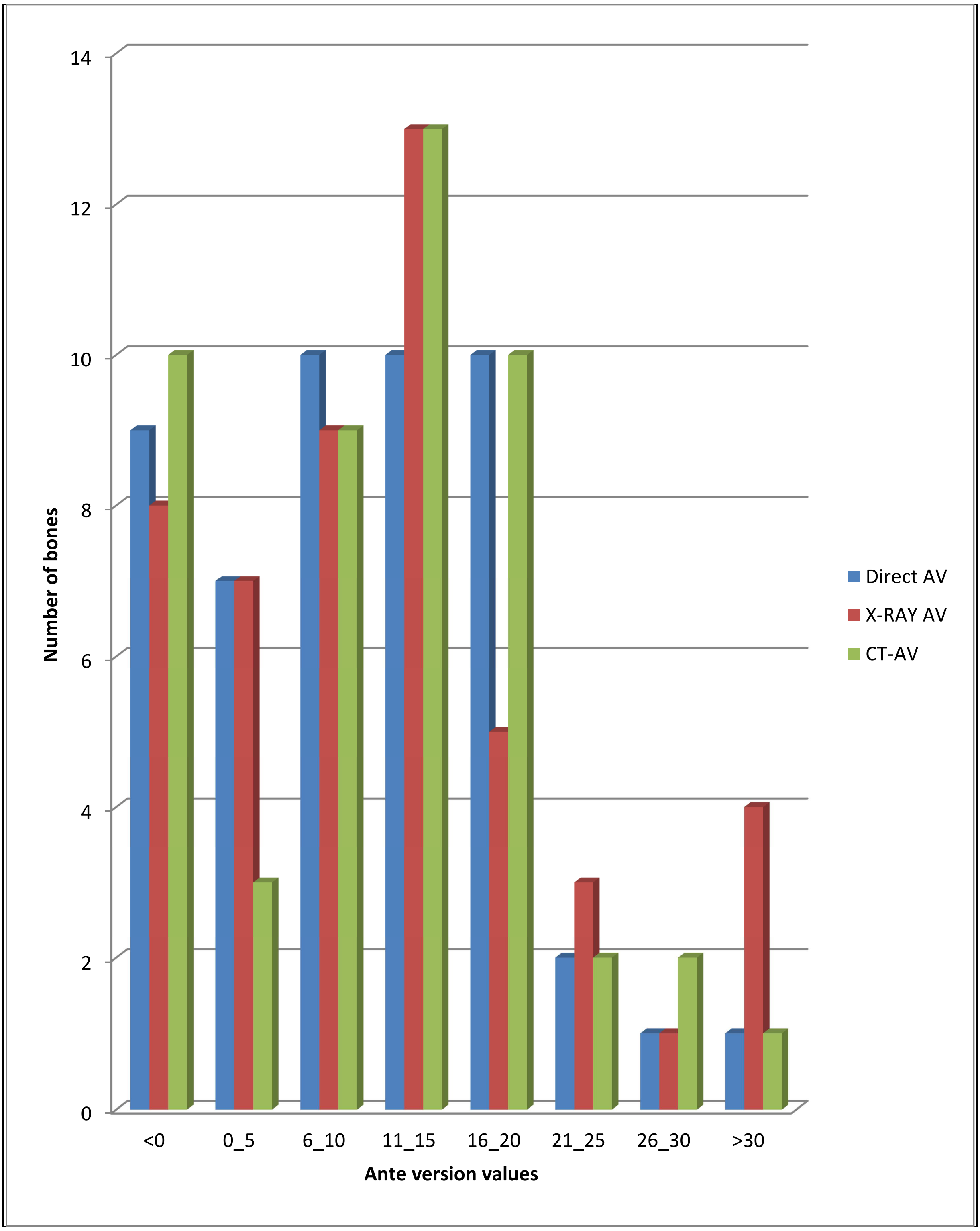

Direct -anteversion
Number of bones
12
10
8
6
4
2
0
AV
<0
0_5
6_10
11 _ 15
16 _ 20
21 _25
26 _30
>30
Direct ante version values

X-RAY ANTE VERSION




CT- ANTEVERSION
Number of bones
0
2
4
6
8
10
12
14
CT-AV
<0
0_5
6_10
11 _ 15
16 _ 20
21 _25
26 _30
>30
CT- anteversion values

Comparision of direct,x-ray and CT measurement of FNA



NPar Tests:

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Direct-AV	50	10.30	9.569	-5	32
X ray-AV	50	10.4142	11.65693	-11.01	37.86
CT-AV	50	9.939	10.0455	-8.7	30.0

Table 2.1 **Describes the measurements of ante version by Direct , Xray and CT methods .**

Friedman Test

Ranks

	Mean Rank
Direct-AV	2.16
X ray-AV	1.95
CT-AV	1.89

Table 2.2 **CT method of ANTEVERSION measurement was observed to be the accurate one among the three methods.**

Group Statistics

	Side	N	Mean	Std. Deviation	Std. Error Mean
Direct-AV	Left	22	9.05	8.737	1.863
	Right	28	11.29	10.223	1.932
X ray-AV	Left	22	9.4941	12.31184	2.62489
	Right	28	11.1371	11.29052	2.13371
CT-AV	Left	22	8.919	8.8686	1.8908
	Right	28	10.740	10.9749	2.0741

Table 2.3 Describes the group statistics of the study. No significant difference observed between left and right femur in all the three methods

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Direct-AV	10.30	50	9.569	1.353
	X ray-AV	10.4142	50	11.65693	1.64854
Pair 2	Direct-AV	10.30	50	9.569	1.353
	CT-AV	9.939	50	10.0455	1.4206
Pair 3	X ray-AV	10.4142	50	11.65693	1.64854
	CT-AV	9.939	50	10.0455	1.4206

Table 2.4 :No statistical significance noted between the measurements of neck shaft angle by all the three methods.

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Direct-AV & X ray-AV	50	.617	.000
Pair 2	Direct-AV & CT-AV	50	.980	.000
Pair 3	X ray-AV & CT-AV	50	.628	.000

Note: ** Denotes significant at 1% level

SCATTER PLOT

Direct ante version VS X-ray ante version

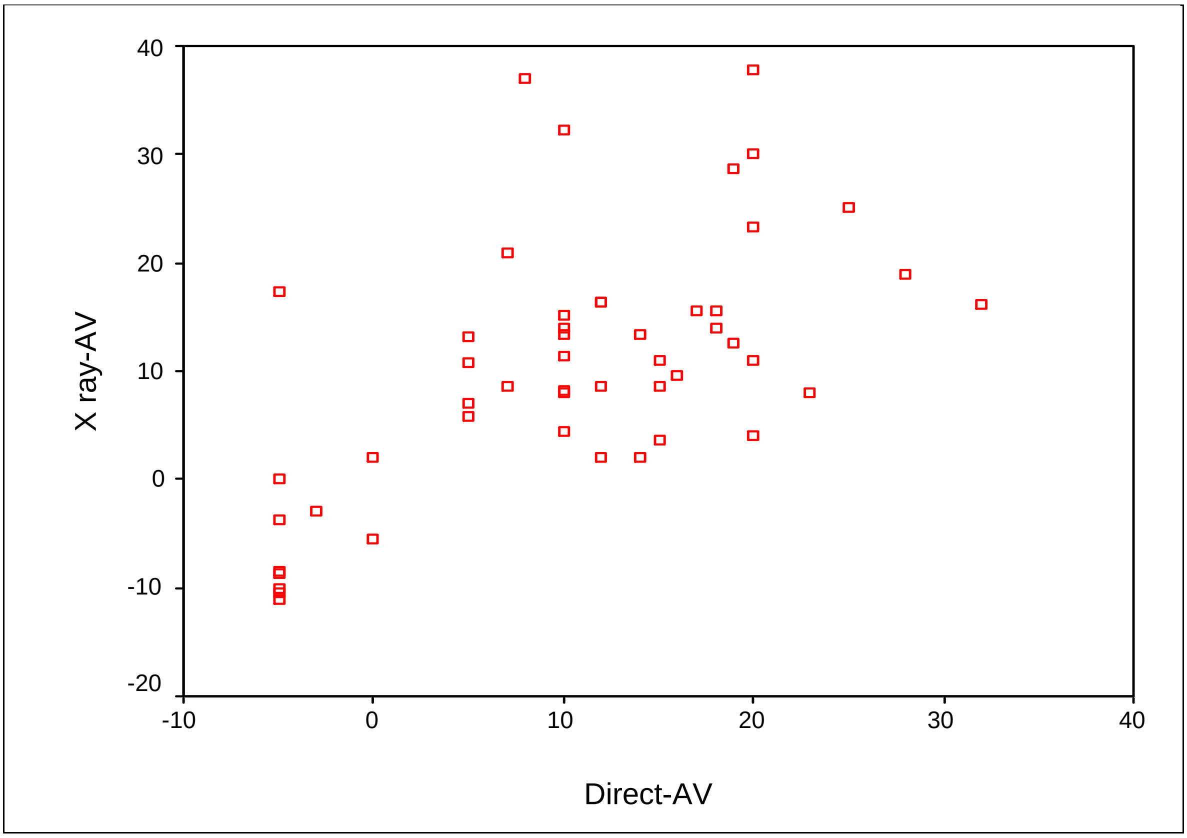


Fig 7.a. Describes the correlation between direct and X –ray guided measurement

SCATTER PLOT

X-ray ante version VS CT- ante version

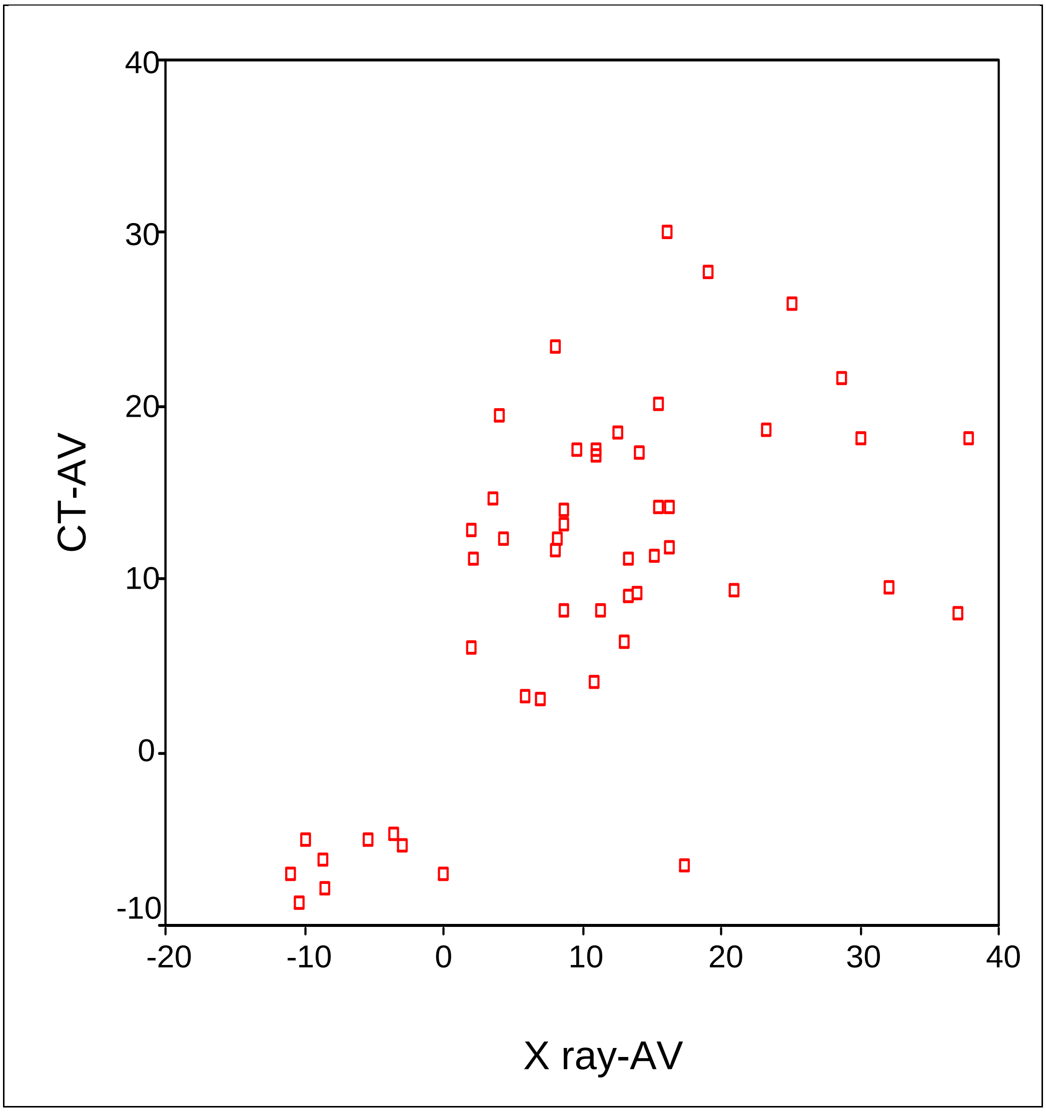
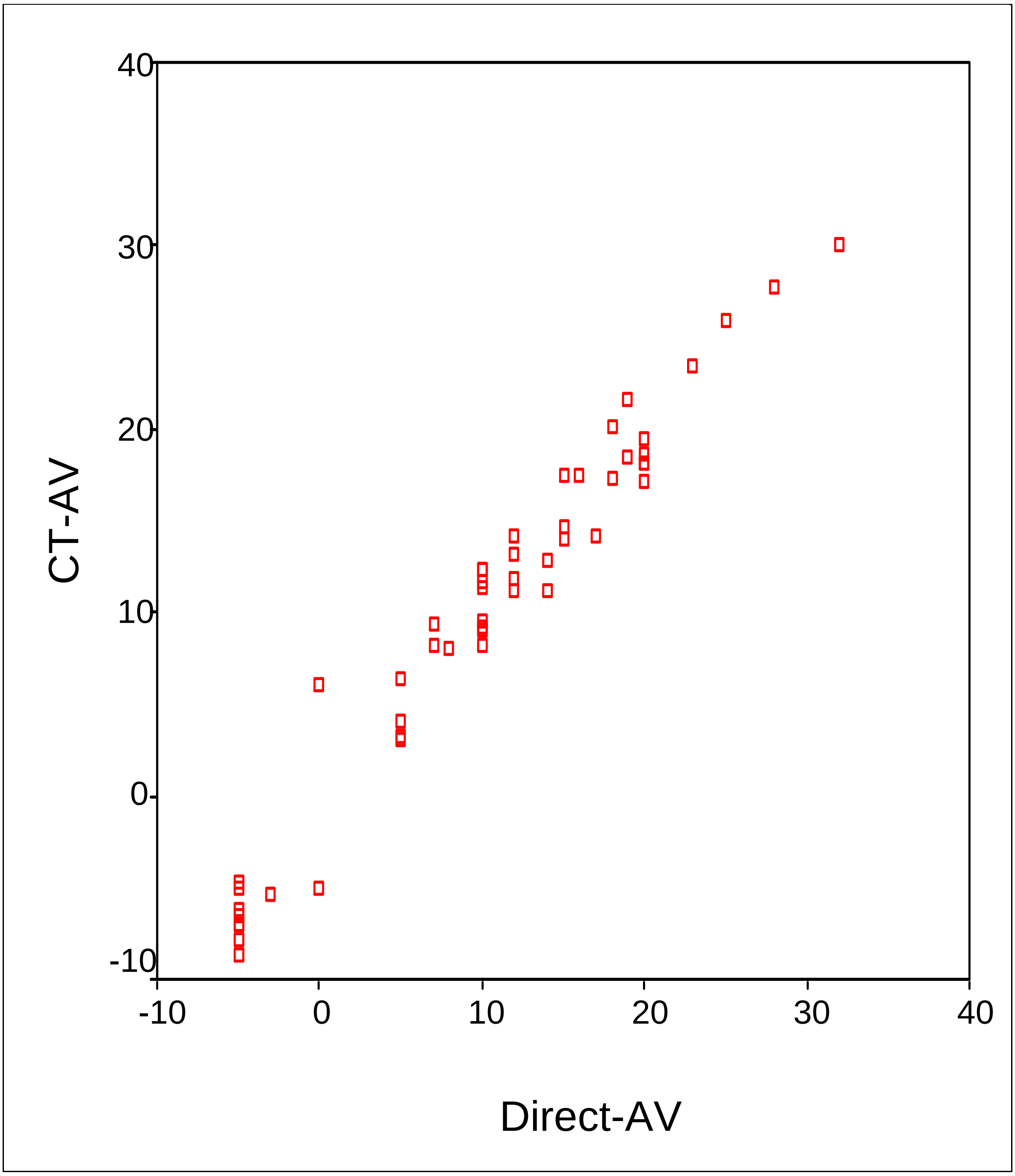


Fig 7.b Describes the correlation between   X –ray and CT guided measurement.

SCATTER PLOT

Direct ante version measurements VS CT- ante version



The mean anteversion angle by Direct, X-ray and CT measurements was found to be 10.3°, 10.4°, 9.9° respectively. Among the three methods the CT-guided method seems to be more accurate to measure the ante version angle by Friedman test result. There was no significant difference in which side (right/left) the sample bone belongs to. Paired T- test was performed in all the possible three pairs of readings and no statistical significance was found with a p value <0.001** (significant with 1% level).With direct measurements as the reference value the standard error of mean was <1.5°.

Retro version

In this study , out of the 50 dry femur bones ,10 showed retroversion . The prevalence of retroversion was 20% with a range of -5 ^{0} to -8^{0} in this study.Kingsley Olmsted reported a prevalence of 14.8% retroversion in his study. In India A K Jain reported a prevalence of 9.3% retro version. Way back in 1963 Kate and Robert published 7.7% prevalence of retroversion in Indian population. In a study conducted by A R Shrikant the prevalence of retroversion was 9.8%.Comparing the prevalence of retroversion in western and previous Indian studies, the prevalence of retroversion is significantly high in this study.

Retroversion is associated with developmental disorders. At 17mm stage of the embryo, the original version of proximal femur is around -10^{0}.Retro version represents the developmental arrest towards the positive side. Due to mechanical, endocrine and developmental factors ,this process of development may go unchecked. This results in retroversion angle in adults. Excessive twisting of lower end of femur outwards was observed to be a cause for retroversion by Parson ,Kate and Robert[11,21].

Table 4.1 Describes the analysis of retroversion of both right &left side femur.

15	126	-5	131	-8.7	128.8	-6.2	L
17	128	-5	132	-8.5	129.02	-7.9	L
24	141	-3	133	-3	138.4	-5.42	L
26	145	-5	139	17.4	142.9	-6.5	R
31	133	0	128	-5.47	134.36	-5	R
32	130	-5	127	-3.64	132.37	-4.7	R
34	138	-5	134	-10.4	139.74	-8.7	R
35	126	-5	126	-11.01	128.8	-7	R
36	132	-5	128	0	135.37	-7	R
48	123	-5	126	-10	127.2	-5	L

Table 4.2 Describes the statistical analysis of the neck shaft angle and anteversion of both right &left side femur.

			Mean	Std Deviation	Standard Error of Mean	Minimum	Maximum	Range	Median	Mode
Side	Left	Direct-NSA	130.73	5.28	1.13	123.00	141.00	18.00	129.50	126.00
		X ray-NSA	129.77	2.86	.61	124.00	135.00	11.00	130.50	132.00
		CT-NSA	132.62	4.60	.98	125.14	139.55	14.41	132.00	132.00
		Direct-AV	9.05	8.74	1.86	-5.00	28.00	33.00	10.00	10.00
		X ray-AV	9.49	12.31	2.62	-10.00	36.99	46.99	8.43	2.02
		CT-AV	8.92	8.87	1.89	-7.90	27.67	35.57	10.35	-7.90
	Right	Direct-NSA	132.89	5.27	1.00	126.00	148.00	22.00	132.00	132.00
		X ray-NSA	130.71	4.84	.92	125.00	147.00	22.00	130.00	126.00
		CT-NSA	134.95	5.16	.97	128.80	148.67	19.87	134.18	130.00
		Direct-AV	11.29	10.22	1.93	-5.00	32.00	37.00	13.50	-5.00
		X ray-AV	11.14	11.29	2.13	-11.01	37.86	48.87	11.13	15.50

DISCUSSION

Comparision of femoral ante version with previous foreign studies. [13,38,39,40,41,42,43,44.]

S.NO	AUTHOR	YEAR	SAMPLE SIZE	POPULATION	METHOD	AV	SD
1	Soutter & Bradford	1903	154	----	Dry bone mechanical	14.3°	-
2	Kingsley	1948	630	American	Dry bone mechanical	8.0°	-
3	FT. Hoaglund	1980	53	Chinese	Dry bone mechanical	M-14.° F-16.°	-
4	Y Yoshioka	1987	32	Canadian	Dry bone mechanical	M-7.0° F-8.0°	-
5	DC Kweon	2002		Korean	CT	20.1°	
6	DC Kweon	2002		Korean	MRI	20.4°	
7	PF Umebese	2005	116	Nigerian	X-ray	28°	5°
8	PA Toogood	2009	375	American	Dry bone digital photo	9.7°	9.3°
9	K Kulig	2010	28	American	USG	20.7°	11°
10	K Kulig	2010	28	American	MRI	19°	11.3°
11	Pock chin toe	2013	3 human subjects	Malaysia	45°oblique view	12°	±2°

S.NO	AUTHOR	YEAR	SAMPLE SIZE	POPULATION	METHOD	AV	SD
12	Present study	2014	50	India	Dry femur mechanical	10.3°	9.5°
13	Present study	2014	50	India	Dry femur Bi planar x-ray	10.4°	11.6°
14	Present study	2014	50	India	Dry femur axial CT	9.9°	10°

The femoral neck ante version in our study on dry femorae was comparable to the studies conducted on dry bone by Kingsley 1948[13],yoshika 1987[40], PA Too good 2009 [42] and a pilot study in Malaysia by Pock chin toe[44].The mean ante version data obtained in our study was 8° to 10° less than the ante version angle data collected from the studies conducted in foreign countries. By analysing the data from these studies it is evident that there is difference in measurement of ante version exists in different population and by different methods used. we compared the results of ante version data from dry femur by mechanical , Bi planar x ray and axial CT method and found CT measurement is more accurate among the three with direct method as reference value.

Though CT measurements are more accurate it is practically difficult to apply the method in large scale screening, risk of high dose radiation especially in paediatric age group and the cost of the investigation. In our study by statistically analysing the results we found that the simple Bi planar x-ray method is equally good as CT in determining the ante version angle .The p value obtained from the paired t test results of bi planar method and CT method showed no statistical significance (p value=<0.001).Thus from this study we can say that this simple bi planar radiography can be substituted for CT measurements.

The CT measurements can be reserved for special situations like cerebral palsy , in toeing and out toeing gait evaluation,dysplastic hip,total hip arthroplasty after acetabular fracture and other deformities related to hip joint and proximal femur.

Comparison of FNA with Indian studies [2,21,22,23,24,25,26].

S.NO	AUTHOR	YEAR	SAMPLE	POPULATION	METHOD	AV	SD
1	Kate	1963	108	-	Dry bone mechanical	8.8°	-
2	RC Siwach	2003	150	Rohtak	Dry bone x-ray	13.7°	7.3°
3	AV Maheshwari	2004	62	Delhi	Bi planar	11.7°	4.6°
4	AV Maheshwari	2004	62	Delhi	clinical	13°	2.6°
5	AK Jain	2005	72	Delhi	CT	7.4°	4.6°
6	AK Jain	2005	138	Delhi	X-ray	11.5°	5.4°
7	AK Jain	2005	138	Delhi	clinical	13.1°	4.6°
8	KC Saikia	2008	92	Guwahati	CT	20.4°	8.6°
9	AR Shrikant	2009	288	Pune	Dry bone mechanical	8.7°	6.6°
10	A Zalawadia	2010	92	Gujarat	Dry bone mechanical	12.4°	18°
11	T Shrimathi	2012	164	Tamil Nadu	Dry bone mechanical	9.8°	-
12	Present study	2014	50	Tamil Nadu	mechanical	10.3°	9.5°
13	Present study	2014	50	Tamil Nadu	Dry bone X-ray	10.4°	11.6°
14	Present study	2014	50	Tamil Nadu	Dry bone CT	9.9°	10°

The results of the present study is comparable with the results of previous Indian studies conducted by Kate et al, AV Jain et al, A k Maheshwari, A Zalwadia and T Shrimathi.[21,23,25,26..] The ante version angle varies between 9⁰ to 12⁰ in Indian population of various region to that of the foreign population with ante version predominantly ranging between 15⁰ to 20⁰.

This data provides a strong evidence for the need of specially devised implants for the Indian population. In advanced surgical techniques the precise measurement of the ante version of that particular patient is an essential component for the success of the procedure.

For example , a study conducted by Lawrence D. Dorr in 2012 on a combined ante version technique for robotic arm guided THA states that ,the cementless stem can only be implanted with in 10⁰ - 20⁰ ante version in less than 50% of the patient.[45] Hence it is essential to determine the pre-op accurate ante version, per operative broach version and the combined ante version, a concept of mating the implants termed by Ranawat.[45]

Not only for advanced surgical techniques, but also for the basic trauma surgeries like DHS, PFN, hemiarthroplasty, cancellous screw fixation and other deformity correction of the proximal femur , the pre-operative determination of the proximal femur angles of that particular patient plays a vital role. It can reduce the duration of surgery, increase the efficiency , outcome of the surgical procedure and to aid normal biomechanics of hip joint.

From this study it is evident that the most accurate data of ante version can be done with CT –measurements for advanced surgical techniques , deformity correction , un co-operative patients and the simple bi planar method can be substituted for CT-measurements for basic trauma surgeries.

Evaluation of Femoral neck shaft angle

Comparison of NSA with foreign studies [38,40,41,46,47,48,49.]

S.NO	AUTHOR	YEAR	SIZE	POPULATION	METHOD	NSA	SD
1	FT Hoagland	1980	55	American	Dry bone mechanical	126.3^0	5.1^0
2	FT Hoagland	1980	53	Chinese	Dry bone mechanical	124.6^0	3.9^0
3	Yoshioka	1987	32	Canadian	Dry bone mechanical	131^0	**-**
4	Rubin	1992	32	French	X-ray	122.9^0	**7.**6^0
5	PF Umebese	2005	96	Nigerian	X ray	121^0	6^0
6	Liang J	2009	56	Chinese	CT	126.2^0	7.1^0
7	HD Atkinson	2010	100	British	CT	M- 129° F- 128°	**-**
8	M Inam	2011	100	Pakistan	X ray	134^0	5.6^0
9	Present study	2014	50	India	mechanical	131.9^0	5.3^0

S.NO	AUTHOR	YEAR	SIZE	POPULATION	METHOD	NSA	SD
10	Present study	2014	50	India	Dry bone X ray	130.3^{0}	4^{o}
11	Present study	2014	50	India	Dry bone CT	133.9^{0}	5^{o}

Analysing the results of the present study on neck shaft angle measurements with that of the foreign studies shows a variation in of 6^{o} to 8^{o} higher neck shaft angle in Indian population. The neck shaft angle measurements in this study are similar to the data obtained from a study conducted by M Inam in 2011 in Pakistan.[46.]

Comparison of NSA with Indian studies:[2,22,27,28,50].

S.NO	AUTHOR	YEAR	SIZE	POPULATION	METHOD	NSA	SD
1	B Isaac	1997	171	Vellore	dry bone mechanical	126.7	-
2	RC Siwach	2003	150	Rohtak	dry bone mechanical	123.5^0	4.3^0
3	RC Siwach	2003	150	Rohtak	Dry bone CT	123^0	4.3^0
4	KC Saikia	2008	92	Guwahati	CT	139.5^0	7.5^0
5	TR Deshmukh	2010	77	Vidharba	X-ray	131.5^0	-
6	Ravichandran et al	2011	578	Tamil Nadu	Dry bone mechanical	126.5^0	-
7	Present study	2014	50	Tamil Nadu	Dry bone mechanical	131.9^0	5.3^0
8	Present study	2014	50	Tamil Nadu	Dry bone Xray	130.3^0	4^0
8	Present study	2014	50	Tamil Nadu	Dry bone CT	133.9^0	5^0

The mean neck shaft angle in the present study was 5^o - 8^o higher side in comparision with the mean neck shaft angle of various regions of India.

B Issac et al in 1997 came with a mean NSA of 126.7.[27]

Subsequently, R Siwach et al in 2003 in Rohtak (India)[28] and Ravichandran et al in 2011 in Tamil Nadu (India) [27]proposed a mean NSA data of 123.5° and 126.5° respectively. [22,28]

Pre operative measurements of neck shaft angle of individual subject is an important concern in many basic and advanced surgical techniques. For example, to perform a metal on metal Hip resurfacing arthroplasty a normal acetabular and proximal femoral morphology ,a neutral femoral neck shaft angle is an essential prerequisite to perform the procedure.[51]

Hence patient specific NSA measurements is a must for pre-operative templating and its clinical application per operatively, as quoted in the study conducted by Alexander S.Mc Lawhorn in 2012 on MoM-HRA.[51]

In our study, the X-ray measurement of neck shaft angle is found to be more accurate among the three methods analysed in the study by Friedman test ranking.

CONCLUSION

In this study conducted by our Institute of Orthopaedics and Traumatology in concurrence with the Bernaud Institute of Radiology and Institute of Anatomy , 50 adult Indian dry femorae were analysed for neck shaft angle and ante version. Direct mechanical, bi-planar x-ray and multi slice axial CT – guided measurements of FNA & NSA obtained .The results were analysed statistically.

- In the present study ,the average NSA was 5-6^{0} higher when comparing the foreign studies as well as the previous Indian studies.
- The average ante version was 5-6^{0} lower than the ante version reported in both previous foreign and Indian studies.
- To measure the NSA, Bi planar X-ray method is more accurate than CT with direct measurements as the reference values.
- To measure ante version, multi slice axial CT is more accurate than bi planar x-ray with direct measurements as the reference values.
- Though CT measurements are more accurate than x-ray measures by Friedman test, there is no statistical significance in ante version between x-ray and CT guided measures by paired t-test analysis.

- Thus from this study it can be concluded that bi planar x-ray method can be substituted for CT measurements of ante version for clinical application, when cross leg lateral view is possible.
- In special occasions like congenital , neuro muscular disorders causing in toeing,out toeing gait and excessive ante version - CT measurements can be used for clinical application.
- There was no significant side difference in NSA and AV by all the three methods of measurements.
- In this study the prevalence of retroversion is 20% which is significantly high when compared to previous studies.
- The data obtained can be used to design patient specific implants , for upcoming future advanced techniques ,pre operative planning and reduce the intra operative complications.

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INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE, CHENNAI-3

EC Reg No.ECR/270/Inst./TN/2013
Telephone No. 044 25305301
Fax : 044 25363970

CERTIFICATE OF APPROVAL

To
Dr. T.Manikandan,
Post Graduate, MS (Orthopaedics),
Institute of Orthopaedics & Traumatology,
Madras Medical College,
Chennai – 600 003.

Dr.T.Manikandan,

The Institutional Ethics Committee has considered your request and approved your study titled **"Evaluation of femoral neck shaft angle and anteversion in dry femorae of adult Indian population"** No.06122013

The following members of Ethics Committee were present in the meeting held on 11.12.2013 conducted at Madras Medical College, Chennai-3.

1. Dr.G.Sivakumar, M.S., FICS., FAIS	: Chairperson
2. Dr.V.Kanagasabai, M.D., Dean, MMC, Ch-3	: Member
3. Prof.B.Kalaiselvi, M.D., Vice-Principal, MMC, Ch-3	: Member Secretary
4. Prof.R.Nandhini, M.D., Inst.of Pharmacology, MMC	: Member
5. Prof.S.Deivanayagam, M.S., HOD of General Surgery , MMC	: Member
6. Prof.Md.Ali, M.D., D.M., HOD, MGE, MMC	: Member
7. Prof.Meena Umachander, M.D., Director i/c IOG,	: Member
8. Prof.K.Ramadevi, Director i/c, Inst.of Biochemistry, MMC	: Member
9. Prof.P.Karkuzhali, M.D., Director of Pathology, MMC	: Member
10. Prof.K.Sivasubramaniam, M.D., Director i/c, IIM, MMC	: Member
11. Thiru S.Rameshkumar, Administrative Officer	: Lay Person
12. Thiru S.Govindasamy, B.A., B.L.,	: Lawyer
13. Tmt.Arnold Saulina, M.A., MSW.,	: Social Scientist

We approve the proposal to be conducted in its presented form.

Sd/ Chairman & Other Members

The Institutional Ethics Committee expects to be informed about the progress of the study and SAE occurring in the course of the study, any changes in the protocol and patients information/informed consent and asks to be provided a copy of the final report.

Member Secretary, Ethics Committee

MEMBER SECRETARY
INSTITUTIONAL ETHICS COMMITTEE
MADRAS MEDICAL COLLEGE
CHENNAI-600 003

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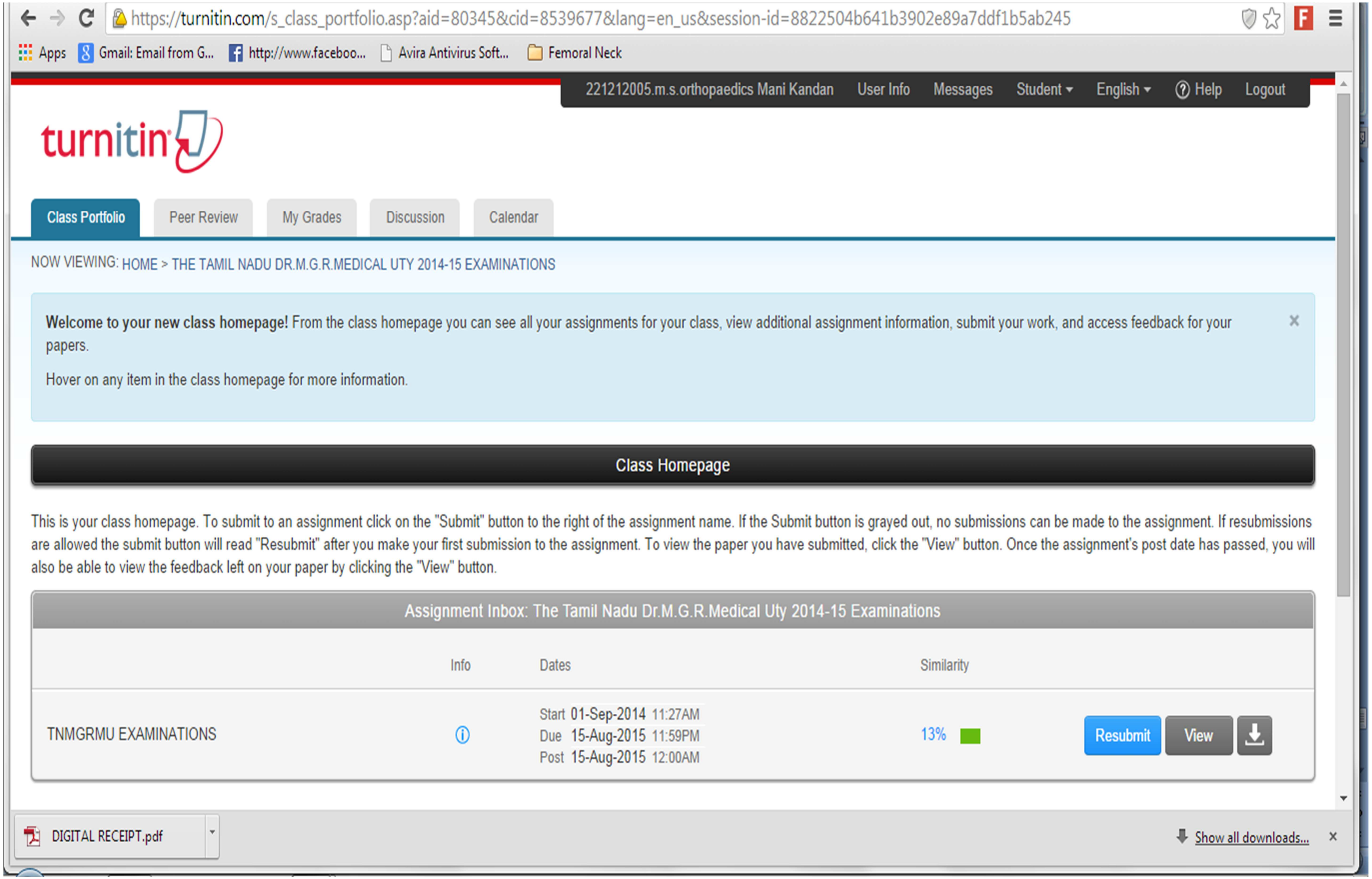
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MASTER CHART

Bone.no	D-NSA	D-AV	X-NSA	X-AV	CT-NSA	CT-AV	R/L
1	125	8	127	36.99	128.7	8.1	L
2	135	20	137	37.86	137.9	18.2	R
3	132	10	133	32.16	132	9.5	L
4	132	10	131	4.34	135.04	12.3	R
5	126	10	126	13.32	128.9	9.05	L
6	132	25	127	25.1	134.04	26	R
7	136	5	132	10.8	139.9	4	R
8	132	15	130	10.95	134.16	17.5	R
9	126	12	127	2.1	125.5	11.2	L
10	130	10	125	11.3	129.1	8.2	R
11	132	5	131	13.1	131.3	6.4	R
12	130	15	126	3.6	129.07	14.6	R
13	137	10	129	8.15	135.86	12.29	L
14	129	10	127	8.05	131.43	11.7	L
15	126	-5	131	-8.7	128.8	-6.2	L
16	140	7	135	20.9	138.91	9.3	L
17	128	-5	132	-8.5	129.02	-7.9	L
18	130	5	132	5.9	137.71	3.2	L
19	134	12	132	16.3	137.54	11.8	L
20	137	12	131	8.7	139.55	13.1	L
21	133	7	131	8.7	135.73	8.29	L
22	136	14	130	13.35	134.67	11.21	L
23	136	28	132	19.01	137.8	27.67	L
24	141	-3	133	-3	138.4	-5.42	L
25	144	19	137	28.64	147.9	21.69	R
26	145	-5	139	17.4	142.9	-6.5	R
27	135	32	134	16.08	138.6	30.01	R

Bone.no	D-NSA	D-AV	X-NSA	X-AV	CT-NSA	CT-AV	R/L
28	128	18	126	15.5	130	20.2	R
29	131	10	132	15.13	133.96	11.3	R
30	129	17	128	15.5	132.9	14.1	R
31	133	0	128	-5.47	134.36	-5	R
32	130	-5	127	-3.64	132.37	-4.7	R
33	148	16	147	9.54	148.67	17.5	R
34	138	-5	134	-10.4	139.74	-8.7	R
35	126	-5	126	-11.01	128.8	-7	R
36	132	-5	128	0	135.37	-7	R
37	131	20	130	10.94	134.3	17.1	R
38	132	23	132	8.11	135.24	23.4	R
39	132	19	128	12.5	134.2	18.47	R
40	127	14	124	2.02	125.14	12.9	L
41	129	0	129	2.02	134.3	6.03	L
42	125	20	129	4.04	130.26	19.4	L
43	126	10	131	14	130	9.2	R
44	132	5	127	7	134.3	3.01	R
45	132	20	131	30.04	134	18.2	R
46	130	20	132	23.32	132	18.6	L
47	126	18	127	14.04	128.26	17.4	L
48	123	-5	126	-10	127.2	-5	L
49	128	12	130	16.3	129.4	14.2	R
50	130	15	126	8.63	131.2	14.04	R